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THE CUTTING EDGE: SCIENCE AND TECHNOLOGY FOR AMERICA'S FUTURE

HEARING

BEFORE THE

SUBCOMMITTEE ON
INVESTIGATIONS AND OVERSIGHT

OF THE

COMMITTEE ON
SCIENCE, SPACE, AND TECHNOLOGY
HOUSE OF REPRESENTATIVES

ONE HUNDREDTH CONGRESS

SECOND SESSION

JUNE 27, 1988

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THE CUTTING EDGE: SCIENCE AND TECHNOLOGY FOR AMERICA'S FUTURE

MONDAY, JUNE 27, 1988

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
SUBCOMMITTEE ON INVESTIGATIONS AND OVERSIGHT,
Bethlehem, PA.

The subcommittee met, pursuant to notice, at 11:30 a.m., at Martin Tower Auditorium, Bethlehem Steel Co., Bethlehem, PA, Hon. Robert A. Roe [chairman of the subcommittee] presiding.

Mr. ROE. The hearing will come to order. We are happy to have you all with us. And, at the outset, I would like to pay my high regard to Dr. Jolley, representing the Bethlehem Steel Company who has been hosting us here today. I want to talk about that a little later on. I certainly want to comment on my high regard for Congressman Don Ritter, who is the representative from this district, as you know. And he is one of our really leading scientists in the Congress and has done an outstanding job—is doing an outstanding job in the future of our country and competitiveness and high technology, all the areas that are important in the future of the United States and where our country is going from here. Having said that, let me get a little formal here.

It is the good fortune of the Committee on Science, Space, and Technology that we are among the first to learn of new and exciting scientific breakthroughs. We are allowed to share in the thrill of scientific discovery, and also have the responsibility for deciding how to allocate the Nation's research funds to make these breakthroughs possible. Today we hope you will come to share that excitement with us and be able to participate particularly with the witnesses with some of your ideas and views, in the direction we should go in prioritizing the Science, Space, and Technology Committee, of our country.

We come to the Lehigh Valley of Pennsylvania because here is where science becomes the technology that will improve all our lives. America depends on its universities for the advancements of knowledge that keep this Nation preeminent in world science. We depend on forward-thinking companies like those testifying before us today to use that fundamental knowledge in the high-quality goods and services customers want to buy.

Today, we begin with a discussion of a subject many of you may identify with personally. It is no secret that the American industries which made our way of life the envy of the world are suffering through some rough seas today, and therefore, so are the

people of our country. This area knows better than most how it feels when customers do not want to buy what you are selling any more. But we are going to recover from that syndrome. We are learning those lessons that we ignored 30 years ago—give American workers the best tools, overcome barriers to communication between labor and management, and really listen to what the customer wants—and success will follow.

There is no miracle involved in the Japanese economic success. Any nation with high-skilled workers can do exactly the same things with the same results—as Tokyo is now beginning to learn. My counterpart in the Japanese Parliament has to think about Korea's—what is that—you know I did not even know what a Hyundai is, but I think it is a little car, is it not? I know, I just wanted to see if you were awake or not. No, seriously I think that the Japanese people are beginning to learn now as they turn away from our constant confrontation with them in competitors—now, of course, their major competitor would be Korea.

Those of you who have been to the store to buy a record album lately know about compact discs. If you have seen commercials for the U.S. Sprint Co., you might remember their fiber-optic telephone network. This is the leading edge of photonics, our second topic today. Telephones and computers use electricity to carry information from place to place. With photonics, light will do that job, as you know. One day, your children might ask to use the encyclopedia, and you will hand them a compact disc. Not only will they be able to read about photonics, but they could watch movies showing scientists working with lasers.

Let me suggest this, I want to be able to leave as much time as we can for those of you that have journeyed to join us here in Pennsylvania, and also I want to have the time to be able to exchange ideas—particularly with the witnesses that are testifying. I am going to cut my statement short and thank you for joining us today and have the chance to introduce our ranking member on our Science, Space, and Technology Investigations and Oversight Subcommittee. Don, as you know, has done a wonderful job, and I am pleased that I am able to join with him today, Don Ritter.

[The prepared statement of Mr. Roe follows:]

OPENING STATEMENT

BY THE

HONORABLE ROBERT A. ROE

CHAIRMAN, SUBCOMMITTEE ON INVESTIGATIONS
AND OVERSIGHT
OF THE
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

JUNE 27, 1988

GOOD AFTERNOON, LADIES AND GENTLEMEN. THE HEARING WILL COME TO ORDER.

IT IS THE GOOD FORTUNE OF THE COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY THAT WE ARE AMONG THE FIRST TO LEARN OF NEW AND EXCITING SCIENTIFIC BREAKTHROUGHS. WE ARE ALLOWED TO SHARE IN THE THRILL OF SCIENTIFIC DISCOVERY. WE ALSO HAVE THE RESPONSIBILITY FOR DECIDING HOW TO ALLOCATE THE NATION'S RESEARCH FUNDS TO MAKE THESE BREAKTHROUGHS POSSIBLE. TODAY WE HOPE YOU WILL COME TO SHARE THAT EXCITEMENT.

WE HAVE COME TO THE LEHIGH VALLEY OF PENNSYLVANIA BECAUSE HERE IS WHERE SCIENCE BECOMES THE TECHNOLOGY THAT WILL IMPROVE ALL OUR LIVES. AMERICA DEPENDS ON ITS UNIVERSITIES FOR THE ADVANCEMENTS OF KNOWLEDGE THAT KEEP THIS NATION PREEMINENT IN WORLD SCIENCE. WE DEPEND ON FORWARD-THINKING COMPANIES LIKE THOSE TESTIFYING BEFORE US TODAY TO USE THAT FUNDAMENTAL KNOWLEDGE IN THE HIGH-QUALITY GOODS AND SERVICES CUSTOMERS WANT TO BUY.

TODAY, WE BEGIN WITH A DISCUSSION OF A SUBJECT MANY OF YOU MAY IDENTIFY WITH PERSONALLY. IT IS NO SECRET THAT THE AMERICAN INDUSTRIES WHICH MADE OUR WAY OF LIFE THE ENVY OF THE WORLD ARE SUFFERING SOME ROUGH SEAS TODAY. THIS AREA KNOWS BETTER THAN MOST HOW IT FEELS WHEN CUSTOMERS DON'T WANT TO BUY WHAT YOU'RE SELLING ANY MORE. BUT WE ARE GOING TO RECOVER. WE ARE LEARNING THE LESSONS THAT WE IGNORED THIRTY YEARS AGO -- GIVE AMERICAN WORKERS THE BEST TOOLS, OVERCOME BARRIERS TO COMMUNICATION BETWEEN LABOR AND MANAGEMENT, AND REALLY LISTEN TO WHAT THE CUSTOMER WANTS -- AND SUCCESS WILL FOLLOW.

THERE IS NO MIRACLE INVOLVED IN JAPANESE ECONOMIC SUCCESS. ANY NATION WITH HIGHLY-SKILLED WORKERS CAN DO EXACTLY THE SAME THINGS WITH THE SAME RESULTS -- AS TOKYO IS NOW LEARNING. MY COUNTERPART IN THE JAPANESE PARLIAMENT HAS TO THINK ABOUT KOREA'S HYUNDAI AND WHAT IT MEANS FOR JAPANESE AUTOMAKERS AND STEELWORKERS.

THOSE OF YOU WHO HAVE BEEN TO THE STORE TO BUY A RECORD ALBUM LATELY KNOW ABOUT COMPACT DISCS. IF YOU'VE SEEN COMMERCIALS FOR THE U.S. SPRINT COMPANY, YOU MIGHT REMEMBER THEIR FIBER-OPTIC TELEPHONE NETWORK. THIS IS THE LEADING EDGE OF PHOTONICS, OUR SECOND TOPIC. TELEPHONES AND COMPUTERS USE ELECTRICITY TO CARRY INFORMATION FROM PLACE TO PLACE. WITH PHOTONICS, LIGHT WILL DO THAT JOB. ONE DAY, YOUR CHILDREN MIGHT ASK TO USE THE ENCYCLOPEDIA AND YOU'LL HAND THEM A COMPACT DISC. NOT ONLY WILL THEY BE ABLE TO READ ABOUT PHOTONICS, BUT THEY COULD WATCH MOVIES SHOWING SCIENTISTS WORKING WITH LASERS.

OUR LAST TOPIC FOR DISCUSSION THIS AFTERNOON IS SUPERCONDUCTIVITY. ONLY TWO YEARS AGO, PHYSICISTS AROUND THE WORLD WERE EXCITED BY A REPORT THAT TWO IBM SCIENTISTS IN SWITZERLAND HAD FOUND A NEW MATERIAL THAT ELECTRICITY COULD PASS THROUGH UNHINDERED. SINCE THEN, WE HAVE HAD REPORTS FROM TEXAS, ALABAMA, ARKANSAS, NEW JERSEY, NEW YORK, CHINA AND JAPAN, EACH REPORTING A HIGHER TEMPERATURE.

WHAT DOES IT ALL MEAN? ANYONE WATCHING TELEVISION OR READING THE NEWSPAPERS PROBABLY REMEMBERS FEVERED SPECULATION ABOUT TRAINS RIDING ON MAGNETIC CUSHIONS, OR SUPERCOMPUTERS ON DESKTOPS, OR AN ELECTRIC CAR. WE ARE NOT HERE TODAY TO ANNOUNCE THE ARRIVAL OF THESE THINGS -- I WISH WE WERE. BUT THEY ARE STILL IN THE FUTURE. WHAT IS IMPORTANT IS THAT WE SUSTAIN THE EFFORT TO FIND OUT HOW THESE NEW MATERIALS WORK AND HOW THEY CAN BE USED. WE ALL KNOW THAT RESEARCHERS IN JAPAN ARE DOING EXACTLY THAT.

I WOULD LIKE TO THANK OUR WITNESSES FOR JOINING US HERE TODAY AND SHARING THEIR INSIGHTS AND EXPERIENCE IN THESE AREAS OF INTEREST TO THE SUBCOMMITTEE. WE LOOK FORWARD TO YOUR TESTIMONY.

AT THIS TIME, I WOULD LIKE TO RECOGNIZE THE SUBCOMMITTEE'S RANKING REPUBLICAN MEMBER, MR. DON RITTER. THE DISTINGUISHED GENTLEMEN FROM PENNSYLVANIA IS NOTED FOR HIS MANY CONTRIBUTIONS TO OUR DEBATES ON SCIENCE POLICY. HIS INTERESTS IN SCIENCE, ENGINEERING AND TECHNOLOGY KNOW FEW BOUNDS. HIS OPENING REMARKS, I'M SURE, WILL DO MUCH TO SET THE STAGE FOR TODAY'S HEARING.

Mr. RITTER. Thank you so much, Mr. Chairman, and thank you for joining us here in the Lehigh Valley to see what has happened in the forefront, as we call it, the "cutting edge," in science and technology, and using science and technology for America's future.

I can tell you that Lehigh Valley unemployment is down to about 4½ percent from well above 10 and in the double digit range just a few years ago. That is better than the national average. Over 1,500 Lehigh Valley companies, mostly small and medium-sized companies, have created thousands of new jobs in the last 5 years.

The President of United States said that we—the residents of the Lehigh Valley—are, and I quote, "building a new economy that is providing jobs and making the country competitive again."

Yet, for all our progress, we know from losses in some of our large industries that we are in an economic Olympics, a race for our technological lives, where science and technology can make or break our performance. Our global competitors are trying to beat us to the punch every way they can, but we are facing up to that challenge.

We are here today to explore a key reason for America's and the Lehigh Valley's successes, and a key feature of our future: commitment to science and technology. We are going to explore the meaning of science and technology to our workplaces, to making our jobs more productive and more profitable and making our products and services more attractive to markets all over America and the world.

The wealth produced by our science and technology enterprise not only drives job creation but makes possible our standard of living, our educational system and our ability to provide for the health and well-being of our citizens. From health care and social security for senior citizens, to program Head Start for our children, new discoveries in science and technology and their application in our economy are the main reason we can pay for those important programs. Indeed, science and technology are the seed corn for the bountiful harvest of modern society.

The Lehigh Valley is taking advanced technology to heart; our citizens are among the Nation's leaders in the development and use of new science and technology. And you will be hearing from some of them today.

Our subcommittee has gathered local and national experts to talk about where some of the most spectacular advances are being made: in superconductivity, photonics, manufacturing sciences, and quality. I call all this the "cutting edge" because these fields are like a blade cutting through the unknown and the unimagined and leading us into the future. Right now, enterprising people are making breakthroughs that promise to change the way we work and live. It is very exciting.

Superconductivity: the very word is energizing. Imagine perpetual motion of electricity. That is what scientists are creating with the new superconducting materials. Perhaps we can build ultra-fast trains that will speed along at 300 mph on cushions of air, criss-crossing the country. Perhaps we will see computers that provide much more information, much faster than ever before, to cure the incurable; or perhaps we will see electrical motors or power transmission lines that will save billions of dollars in wasted energy

every year, and that in turn lowers our monthly electricity bills. Frankly, we cannot begin to imagine the possibilities if this scientific advance becomes commercial reality.

Photonics is the leap beyond electronics. Imagine light beams replacing all the wires in your house, creating a "smart" home. That is the promise of photonics. It is the study of sending signals and messages with light particles or light waves instead of electricity. Perhaps we will build an optical computer that is 1,000 times faster than the fastest computer we have ever built. Think of such a tool to solve the unsolvable. Right now we're seeing more and more of our nation's phone calls on tiny glass fibers, and we can use those same fibers to bring affordable picture phones or radically improved TV into our homes.

Imagine the factory of the future, where man and his machine work together in a way that is not only efficient but enjoyable. That is the goal of research and development in advanced manufacturing sciences. But the advances in equipment will not by themselves make our companies competitive. We also need a revolution in the way that people work with machines and the way they work together and the way companies work with their employees. That human resources revolution may be the most exciting one of all.

Managers and workers committing themselves to total quality, to constantly improving the way that products and services are produced and delivered, leads to dramatic results. By committing to quality, we can improve productivity, enhance work life, and keep our jobs here in America.

Right here in the Lehigh Valley we are engaged in a bold experiment to accelerate the spread of quality principles, called Quality Valley, USA. You will be hearing from witnesses from two companies—one here in the Valley, and one from another state—which have made substantial gains by committing themselves to quality.

To best address the nation's future, teamwork and cooperation between our private sector, government and our educational institutions are essential. Today we will hear from Federal agencies such as the super high-tech Defense Advanced Research Projects Agency [DARPA], the National Science Foundation [NSF], and the National Bureau of Standards,[1] which are major players in the national and global R&D arena. They are doing work that is vital to our success in these cutting-edge fields. We will also be hearing from witnesses from industry and universities, who will tell us what is being done now, and what needs to be done to keep America on top.

Finally, I would like to thank the distinguished chairman of the Science, Space, and Technology Committee, my colleague and good friend, neighboring New Jersey Congressman Bob Roe, for convening this hearing. There is no one in Congress who is a more forceful advocate for the strengthening of America's science and technology programs than you, Mr. Chairman; and I salute you for recognizing that the Lehigh Valley of Pennsylvania has much to offer in these cutting edge fields.

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[1] The National Bureau of Standards was renamed the National Institutes of Standards and Technology in Public Law 100-418, the Omnibus Trade and Competitiveness Act of 1988.

I would also like to welcome and thank all of our witnesses, our guests from afar and our local stars of science. I would also like to thank all of you for attending from the Valley who took time out from your schedules to attend this hearing.

Last but not least, I would like to thank the Bethlehem Steel Company for providing us with this excellent auditorium. Ladies and gentlemen, it is symbolic of the change sweeping American industry that we are here in a steel company auditorium discussing subjects like superconductivity, photonics and robotics—but then again, steel today must be high-tech if it is to survive and prosper.

With that, I would like to introduce Dr. William Jolley of the Bethlehem Steel Company, who has some opening remarks. Thank you, Bill.

[The prepared statement of Mr. Ritter follows:]

OPENING STATEMENT OF HON. DON RITTER, A REPRESENTATIVE FROM THE STATE OF PENNSYLVANIA

Lehigh Valley unemployment is down to about 4½ percent from double digits just a few years ago. That's better than the national average. Over 1,500 Lehigh Valley companies, mostly small and medium-sized companies, have created thousands of new jobs in the last 5 years.

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The wealth produced by our science and technology enterprise not only drives job creation but makes possible our standard of living, our educational system and our ability to provide for the health and well being of our citizens. From health care and social security for senior citizens to program Head Start for our children, new discoveries in science and technology and their application in our economy are the main reason we can pay for those important programs. Indeed, science and technology are the seed corn for the bountiful harvest of modern society.

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the fastest computer ever built. Think of such a tool to solve the unsolvable. Right now we're sending more and more of the nation's phone calls on tiny glass fibers, and we can use those same fibers to bring affordable picture telephones or radically improved TV into our households.

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Managers and workers committing themselves to total quality, to constantly improving the way that products and services are produced and delivered, leads to dramatic results; by committing to Quality, we can improve productivity, enhance work life, and keep jobs here in America.

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To best address the nation's future, teamwork and cooperation between the private sector, government and our educational institutions are essential. Today we'll hear from federal agencies such as the super high-tech Defense Advanced Research Projects Agency (DARPA), the National Science Foundation (NSF), and the National Bureau of Standards, which are major players in the national and global R&D arena. They're doing work that's vital to our success in cutting-edge fields., We'll also be hearing from witnesses from industry and universities who'll tell us what's being done now, and what needs to be done to keep America on top.

Finally, I'd like to thank the distinguished chairman of the Science, Space, and Technology Committee, my colleague and good friend, neighboring New Jersey Congressman Bob Roe, for convening this hearing. There's no one in Congress who's a more forceful advocate for strengthening America's science and technology programs than you, Mr. Chairman, I salute you for recognizing that the Lehigh Valley of Pennsylvania has much to offer in these "cutting edge" fields.

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With that, I would like to introduce Dr. William Jolley of the Bethlehem Steel Company, who has some opening remarks.

STATEMENT OF DR. WILLIAM JOLLEY, GENERAL MANAGER, TECHNOLOGY AND QUALITY ASSURANCE, BETHLEHEM STEEL CORP.

Dr. JOLLEY. Mr. Chairman, Congressman Ritter, and panel members, welcome to Bethlehem and, in particular, Bethlehem Steel Corporation. As Don mentioned, my name is Bill Jolley, and I am the general manager of technology and quality assurance at Bethlehem Steel. It is appropriate to hold this hearing on science and technology at Bethlehem Steel, since our company, like many other manufacturing organizations, has been significantly impacted by the rapid advancements in technology achieved by our overseas competitors.

Many people refer to steel and other basic manufacturing industries as "Rust Belt" industries, implying that we are an old industry using yesterday's technology. This is far from the truth. Although we may be an old industry, historically we have been on the cutting edge of technology and, over the years, we have continued to install many technological improvements. Today, we are not

a low-tech industry. You only have to see a modern continuous caster or hot strip mill with their computerized process controls to realize that technical sophistication is inherent in such operations. In the 1950's and 1960's, the United States was the world leader in developing and adopting new technologies in the manufacturing industries. However, in the 1970's and 1980's, this progress slowed because of capital shortages as imports increased and consumption leveled off. The steel industry's lack of profitability and its need to drastically cut costs in recent years has aggravated this problem through reductions in research staffs. Consequently, in order to increase our competitiveness, we are now in the unenviable position of having to depend mainly on technology developed overseas. Also, there are fewer scientifically-trained people available to adopt this new technology. It would be difficult to remedy this problem by simply hiring researchers from universities. Fewer and fewer American students have been inclined to obtain advanced degrees in the engineering and scientific disciplines. Furthermore, our industry has reduced its research grants to universities, and the obvious result has been to discourage what few graduate students there are from working in steel-related industries.

In summary, in an industry which is technologically sophisticated, we have a significantly diminished effort in new technology development, and have a very limited ability to recruit the people required to reverse this situation. I am sure this also applies to many other basic manufacturing industries in the United States.

To some extent, recent congressional developments such as the "Steel Initiative," the Report of the Technology Policy Task Force of Chairman Roe's Committee on Science, Space, and Technology, and Congressman's Ritter's program on quality improvements in industry and education are all beginning to address these problems.

The "Steel Initiative" provides welcome funds for steel R&D and, as a member of the AISI Committee on Technology, I have recently been involved in approving the AISI Direct Steelmaking Proposal which we plan to present to the Department of Energy for "Steel Initiative" funds later this year. Also, Bethlehem has just submitted a proposal for funding from the DOE's Clean Coal Program.

The Technology Policy Task Force has, among many other things, recognized the need for more qualified engineering graduates in the United States—something we can relate to as we try to replenish our technical resources.

Don Ritter's quality program is emphasizing at the government level the contribution that quality makes to our industrial competitiveness, both directly and through our education system.

We hope that these types of initiatives will continue, and we in the industry are prepared to give you all the support we can. Once again, welcome to Bethlehem and good luck in your discussions and deliberations today. Thank you.

[The prepared statement of Dr. Jolley follows:]

THE CUTTING EDGE

SCIENCE AND TECHNOLOGY FOR AMERICA'S FUTURE

MR. CHAIRMAN, CONGRESSMAN RITTER, AND PANEL MEMBERS, WELCOME TO BETHLEHEM AND, IN PARTICULAR, TO BETHLEHEM STEEL CORPORATION. MY NAME IS DR. JOLLEY AND I AM THE GENERAL MANAGER OF TECHNOLOGY AND QUALITY ASSURANCE AT BETHLEHEM STEEL. IT IS APPROPRIATE TO HOLD THIS HEARING ON SCIENCE AND TECHNOLOGY AT BETHLEHEM STEEL, SINCE OUR COMPANY, LIKE MANY OTHER MANUFACTURING ORGANIZATIONS, HAS BEEN SIGNIFICANTLY IMPACTED BY THE RAPID ADVANCEMENTS IN TECHNOLOGY ACHIEVED BY OUR OVERSEAS COMPETITION.

MANY PEOPLE REFER TO STEEL AND OTHER BASIC MANUFACTURING INDUSTRIES AS "RUST BELT" INDUSTRIES, IMPLYING THAT WE ARE AN OLD INDUSTRY USING YESTERDAY'S TECHNOLOGY. THIS IS FAR FROM THE TRUTH. ALTHOUGH WE MAY BE AN OLD INDUSTRY, HISTORICALLY WE HAVE BEEN ON THE "CUTTING EDGE" OF TECHNOLOGY AND, OVER THE YEARS, WE HAVE CONTINUED TO INSTALL MANY TECHNOLOGICAL IMPROVEMENTS. TODAY, WE ARE NOT A LOW-TECH INDUSTRY. YOU ONLY HAVE TO SEE A MODERN CONTINUOUS CASTER OR HOT STRIP MILL WITH THEIR COMPUTERIZED PROCESS CONTROLS TO REALIZE THE TECHNICAL SOPHISTICATION THAT IS INHERENT IN SUCH OPERATIONS.

IN THE 50'S AND 60'S, THE UNITED STATES WAS THE WORLD LEADER IN DEVELOPING AND ADOPTING NEW TECHNOLOGIES IN THE MANUFACTURING INDUSTRIES. HOWEVER, IN THE 70'S AND 80'S, THIS PROGRESS SLOWED BECAUSE OF CAPITAL SHORTAGES AS IMPORTS GREW AND CONSUMPTION LEVELED OFF. THE STEEL INDUSTRY'S LACK OF PROFITABILITY AND ITS NEED TO DRASTICALLY CUT COSTS IN RECENT FEW YEARS HAS AGGRAVATED THIS PROBLEM THROUGH REDUCTIONS IN RESEARCH STAFFS. CONSEQUENTLY, IN ORDER TO INCREASE OUR COMPETITIVENESS, WE ARE NOW IN THE UNENVIABLE POSITION OF HAVING TO DEPEND MAINLY ON TECHNOLOGY DEVELOPED OVERSEAS. ALSO, THERE ARE FEWER SCIENTIFICALLY-TRAINED PEOPLE AVAILABLE TO ADOPT THIS NEW TECHNOLOGY. IT WOULD BE DIFFICULT TO REMEDY THIS PROBLEM BY SIMPLY HIRING NEW RESEARCHERS FROM UNIVERSITIES. FEWER AND FEWER AMERICAN STUDENTS HAVE BEEN INCLINED TO OBTAIN ADVANCED DEGREES IN THE ENGINEERING AND SCIENCE DISCIPLINES. FURTHERMORE, OUR INDUSTRY HAS REDUCED ITS RESEARCH GRANTS TO UNIVERSITIES, AND THE OBVIOUS RESULT HAS BEEN TO DISCOURAGE WHAT FEW GRADUATE STUDENTS THERE ARE FROM WORKING IN STEEL-RELATED TECHNOLOGIES.

IN SUMMARY, IN AN INDUSTRY WHICH IS TECHNOLOGICALLY SOPHISTICATED, WE HAVE A SIGNIFICANTLY DIMINISHED EFFORT IN NEW TECHNOLOGY DEVELOPMENT AND HAVE A VERY LIMITED ABILITY TO RECRUIT THE PEOPLE REQUIRED TO REVERSE THIS SITUATION. I'M SURE THIS ALSO APPLIES TO MANY OTHER BASIC MANUFACTURING INDUSTRIES IN THE UNITED STATES.

TO SOME EXTENT, RECENT CONGRESSIONAL DEVELOPMENTS SUCH AS THE STEEL INITIATIVE, THE REPORT OF THE TECHNOLOGY POLICY TASK FORCE OF CHAIRMAN ROE'S COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY, AND CONGRESSMAN RITTER'S PROGRAM ON QUALITY IMPROVEMENTS IN INDUSTRY AND EDUCATION ARE ALL BEGINNING TO ADDRESS THESE PROBLEMS.

THE STEEL INITIATIVE PROVIDES WELCOME FUNDS FOR STEEL R&D AND, AS A MEMBER OF THE AISI TECHNOLOGY COMMITTEE, I HAVE RECENTLY BEEN INVOLVED IN APPROVING THE AISI DIRECT STEELMAKING PROPOSAL WHICH WE PLAN TO PRESENT TO THE DEPARTMENT OF ENERGY FOR STEEL INITIATIVE FUNDS LATER THIS YEAR. ALSO, BETHLEHEM HAS JUST SUBMITTED A PROPOSAL FOR FUNDING FROM THE DOE'S CLEAN COAL PROGRAM.

THE TECHNOLOGY POLICY TASK FORCE HAS, AMONG MANY OTHER THINGS, RECOGNIZED THE NEED FOR MORE QUALIFIED ENGINEERING GRADUATES IN THE UNITED STATES -- SOMETHING WE CAN RELATE TO AS WE TRY TO REPLENISH OUR TECHNICAL MANPOWER. DON RITTER'S QUALITY PROGRAM IS EMPHASIZING, AT THE GOVERNMENT LEVEL, THE CONTRIBUTION THAT QUALITY IMPROVEMENT MAKES TO OUR INDUSTRIAL COMPETITIVENESS, BOTH DIRECTLY AND THROUGH OUR EDUCATIONAL SYSTEM.

WE HOPE THAT THESE TYPES OF INITIATIVES WILL CONTINUE, AND WE IN THE STEEL INDUSTRY ARE PREPARED TO GIVE YOU ALL THE SUPPORT WE CAN. ONCE AGAIN, WELCOME TO BETHLEHEM AND GOOD LUCK IN YOUR DISCUSSIONS AND DELIBERATIONS TODAY.

WJ:SCH
6/27/88

Mr. ROE. Thank you, Dr. Jolley. We appreciate your hosting us today, and we thank you for your statement. Our first panel, on Manufacturing Sciences and Quality, will be Dr. Roger Nagel, the Harvey Wagner Professor of Manufacturing and Engineering, Lehigh University, Dr. Nagel. And we have Mr. Samuel Kramer, Deputy Director, National Engineering Laboratory, National Bureau of Standards. Mr. Kramer is here. Mr. Francis Jackson, director of quality management planning, Eastman Chemical Division, Eastman Kodak Company; Mr. Ed Alkire, director of quality and safety, industrial gas division, Air Products and Chemicals, Inc.

We want to welcome all of our witnesses to the hearing. And the first witness to testify will be Dr. Roger Nagel of Lehigh University.

Now, you know we—I know there is some constraint on time, but I do not want to—I want to have the advantage of our full testimony so we can discuss hopefully and have a chance to review.

STATEMENT OF DR. ROGER N. NAGEL, HARVEY E. WAGNER PROFESSOR OF MANUFACTURING SYSTEMS ENGINEERING, LEHIGH UNIVERSITY, BETHLEHEM, PA

Dr. NAGEL. Thank you very much. It is my privilege and pleasure to be here this morning and to make some remarks that I hope will qualify issues where I can help in providing an understanding of what I consider the importance of manufacturing and manufacturing R&D to the Nation.

I want to summarize what I will say, by suggesting that I think we need to understand better the impact of the manufacturing economy or the manufacturing sector on the United States, and that it really is a critical factor in affecting the standard of living of our country.

I will then try and discuss some of the factors controlling the health of manufacturing and that sector by responding to questions you asked me about education, our vision of the factory of the future, technology transfer and applied R&D, fundamental R&D and the role of United States R&D vis-a-vis its global competitors.

And finally, I will close with some remarks where I think the government should take action or do things to facilitate action. I might summarize that by saying, I think the government needs to act to foster the health of manufacturing in a widened self-interest with the United States. By manufacturing, I want to clarify that I do not simply mean the production facilities of the various companies and their factories; but rather, we mean the manufacturing companies of the entire enterprise that is involved with manufacturing. And it is important to focus on the fact that the whole company is really where our attentions are and not just in the production section. In fact, one of the lessons we have learned is that one cannot separate and isolate the various components of an enterprise, by saying the manufacturing is okay, but engineering needs help, etc.

There is a danger that people loosely make an analogy in the change that took place from a farm economy to an manufacturing economy in the past in saying, well we are simply evolving from

maybe a manufacturing economy to a service economy where there will be more jobs in the service sector than there are in the manufacturing sector and that is going to have a similar impact.

Well, one has to be very careful there. We retained the farm economy by automating the farm. And so 3 percent of the nation now does the work that used to be done by 90 percent. In the manufacturing sector, there is evidence that we are losing manufacturing industry. That is very different than retaining it. Automation will in fact help us to take steps to regain and maintain competitiveness, but automation of the workers' muscles is not the only thing that we need to do. And as I will say later on, we need to work on augmenting man's brain and making him more powerful with the appropriate new technologies that are coming into place.

Now, let me say one more thing about popular myths in terms of changing from a kind of a manufacturing sector to a service sector. Steven Cohen and John Zysman put a book out called "Manufacturing Matters," [2] and I will summarize the important points that they made, is that there are 20 million jobs in the manufacturing sector; but they are tightly and intimately linked to 40 million jobs in the service sector; the accountants, the people who serve food, the people who provide the very services to those companies. If we change from being a manufacturing sector by having those companies go overseas, than 60 million jobs are at stake, not just 20 million. As we lose portions of industries, we lose larger proportions than the statistics might say.

Dennis Swyt of the National Bureau of Standards did a study of the pattern of the work force, suggesting that if we look at four categories of worker, engineering and technical professionals, manufacturing and administrative workers, service sector workers, and production workers, that one can then look at how the shift in each of those categories has been taking place over time, and the only one of those categories that is growing at an increasing rate is engineering and technical professionals, which suggests that we are not switching to an economy of a lot of "Hamburger Helper"-type people in the service sector, but rather to people with more training in engineering and technical professional areas, which agrees with our notion that competition is going to be based more and more not on automation or the things that man did with his muscle, but rather in augmenting the things that man does with his brain. The intellect and the power of people in the engineering and technical profession will be the basis on which we compete successfully and maintain a manufacturing economy, or in fact we'll see it shift overseas.

I do not want to spend a lot of time right now on the importance of the Department of Defense in manufacturing and how they are based on each other, because that has been the subject of many other forums. Let me simply say that I do feel that manufacturing is very much dependent currently on the support it gets from the Department of Defense and vice versa, and that right now I think we have some challenges to restore the health of the industrial

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[2] Stephen S. Cohen and John Zysman, *Manufacturing Matters: The Myth of the Post-Industrial Economy* (New York: Basic Books, Inc., 1987).

base to make our confidence in DOD's ability to respond to surge mobilization and other mandates more comfortable.

If I have in your mind established the criticality of manufacturing for the United States, let me now look at some of the factors that affect its health. I will try to mention education, tech transfer and R&D, if you will. I am concerned that right now there is not enough demand for the graduates of our educational institutions in the manufacturing systems area. That if that demand were to reach the heights and levels that it should reach in order to be making our industries more competitive, that we probably do not have the instantaneous capacity or ability to put out that number of graduates. So we suffer both from not realizing we need more of something, and therefore, not building the capability to provide it. There are, of course, exceptions, and we hope that Lehigh and some of the other institutions that are acting as exceptions right now, will be multiplied through our sister institutions.

I want to say a few words about the special program we instituted at Lehigh in this direction to give you some feeling for the kinds of difference between programs designed in this area and others. It is unique because:

It is interdisciplinary; it combines the efforts of people in several departments and in fact several colleges.

It is unique because full-time employees are assigned to Lehigh to get a degree as an important thing for them to do for their company. It is unique because of the informal activities as well as the formal ones that combine to create an atmosphere of team work and cooperation which is required in modern manufacturing.

It is unique because our goal is not technology alone but to deal with systems that are made up of people, machines, information and technology in an appropriate balance. And that is a new realization of recent times.

We like to think that everything that is good can be measured, and we can see how good it is from those measures. And early measurements of the placement statistics and the recruiting statistics of this program, and the companies that are willing to put money up just to do it better, indicate in fact that we are doing the job that needs to be done more often and to be cloned, if you will.

You asked that I talk about the "Factory of the Future." I would like to do so just briefly, because I think the factory of the future is only one component of the enterprise of the future. But it is a mistake again, to look at the obvious technologies like robotics and computers which you can touch and feel, and not understand the changes that are taking place in the entire enterprise.

There will be and there must be tight linkages and new organizational structures between the production capabilities, engineering, marketing sales and service. Those things are taking place, and we need to overcome the inertia of the old way of doing business to be able to accept and utilize technology to its fullest.

There has been a recognition that there is more technology available than we are successfully implementing. Therefore, there has been a lot of focus on shortening the time of technology transfer and putting aids in place for that. The state of Pennsylvania started the Ben Franklin Program which spends a lot of its energies and efforts in the technology transfer area. I believe that is a good

program, because it allows companies and industry to partner, choose their emphasis area, and then the government's money, in this case the state's money, is used to leverage what industry and the university feel they could do effectively together. The state measures the success of that in terms of new jobs or jobs retained, new products, new processes and the competitive health of the companies effected in the state of Pennsylvania.

This success is not unique to Pennsylvania, and is being replicated by other states and is in fact being looked at as the way of organizing the Hollings Center, not only the Ben Franklin Program, but other models are being used there. In my mind the notion of "We must do something about technology transfer" is widely recognized by the three communities involved; academia, industry and the Government.

Models are being tried, and the scale up that is needed is being put in place. But what is missing from that opportunity is the funding of centers of excellence, to have the Lehighs of the future ready when this time comes again. There is a lack of funding for basic creation of organizational entities at lots of other universities, and for strengthening the ones that exist. There is also a lack of appropriate R&D funding. The future things that we can do 5 or 10 years from now are not being seeded at the rate that we are going to need them to be seeded, if in fact we get over the notion of being able to transfer technology and put it in place. And so, I am worried that there is not a understanding of the appropriate mix of funding that is required.

You asked me to comment on the general status and health of manufacturing systems, research and development. I think there are three areas in which we do that research and development.

The first of those I call the component technologies. And it is the research we do into fundamental materials and the processes to transform those materials in a way that we control them. In that area I have to say that in the old days we relied on established practices and procedures and did not perceive the need for scientific understanding as much as we should have. And so there has been a lack of knowledge available now that computers are able to take advantage of that knowledge; and we are behind in the basis on which to create models for the rapid introduction of new technologies. It is an area that we are catching up on, and there are pockets of excellence and things happening, but much more is needed.

The second area is the one that I call information integration, and is based on computers and data bases and networks and artificial intelligence. Here we have maintained a position of leadership, but we are not out there alone. The importance of this to manufacturing technology and manufacturing enterprises is recognized by global competitors, and we are at least being challenged for a position of leadership. But I believe we are still strong in that area, and it is an area that we need to continue to nurture and develop.

The third area is an area that is much newer in the areas of research and development, and it is one that combines engineering and business into looking at organizational issues, technological issues and the strategy to bring technology and organization into place to make an industry more competitive. The reason it is so

new is that it brings together people that used to not talk to each very much. Lehigh and other places where business and engineering faculty work together are considered to be unique, and we are making progress at all those institutions, but not nearly enough or rapidly enough. I do not feel able to judge how we stand in that particular component of competition with what is going on overseas except to know that we are not alone in knowing we need to combine those forces.

I do not see any reason why the United States cannot be a world leader in competitive manufacturing enterprises. It simply means that we have to make some changes in the way we do business, and the way we measure things, and the way we choose our partners. And there is evidence that is beginning to happen.

I would like to close out my testimony with the role of the Government. I think you need to foster the health of the manufacturing economy out of enlightened self-interest, because the standard of living of our people depends on it.

There are some places where the Government could be an impediment to progress. And that deals with a lack of consistency. People do not want to make decisions when they think the Government is going to change the ball game or the rules. So a lot of publicity about the tax changes and the R&D support and things of that nature are substance counterproductive just because the game is going to change and people will wait to make decisions until the game changes, and then they do not know how long it will stay the same.

In some cases, I think the lack of a Government advocate for the manufacturing sector hurts us. There is nobody whose responsibility is to make sure all the Government is focusing on the R&D needs of manufacturing or even on setting an agenda for manufacturing or on coordinating.

I think there is some positive things that you can do, and you should do immediately. And one would be to declare a priority for education in the engineering and technical profession; to make that a national priority. To see that more of our undergraduates look to majoring in these areas, and to provide incentives for our graduate students, particularly American graduate students, people who live and work in the United States when they graduate to go to graduate school by making more and not less loans and fellowships available. I think it is wrong to have tax disincentives for graduate education, and we have been doing that and correcting that too slowly to my mind. Suddenly taxes on tuition and stipends were questioned, and we still have taxes on tuitions. The whole attitude that it is not for the person, I think we need to do it for the nation. Not to get a graduate student a benefit to be able to go to school, but we need more American graduate students in these areas for the nation itself.

Finally, I think the Government has an agenda to set. That is the R&D agenda for manufacturing is something that should be set by the U.S. Government in some agency and that they should coordinate better and increase the amount of R&D funding. In various ways, I have reviewed frequently Government R&D funding and find it to be not coordinating and frankly not enough to make impacts that I think are required.

I want to thank you for the opportunity to have testified, and I hope I can answer any questions you might have.

[The prepared statement of Dr. Nagel follows:]

ADVANCED COPY OF TESTIMONY TO BE GIVEN TO:

U. S. HOUSE OF REPRESENTATIVES

COMMITTEE

ON

SCIENCE, SPACE AND TECHNOLOGY

JUNE 27, 1988

BY ROGER N. NAGEL
HARVEY E. WAGNER PROFESSOR OF
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I want to begin by thanking the committee on Science, Space and Technology for giving me the opportunity to testify today. I hope I can help clarify issues which will aid in the important process of restoring and maintaining a position of leadership for the United States in the world market place for manufactured goods. I would like to begin by discussing why manufacturing is in fact a critical issue. I will then cover several factors which influence the manufacturing health of the U. S. and which I was asked to speak about in my invitation to testify. In this modality I will cover the impact of education; our vision of the factory of the future; status and criticality of research and development efforts; and the role of the federal government to foster the overall health of the manufacturing economy out of enlightened self interest.

When I use the term manufacturing, I am not referring only to the production facilities of various manufacturing companies. I am concerned with <u>all</u> aspects of the manufacturing enterprise. Technological changes in manufacturing have altered the rules of competition. They have created a worldwide, customized marketplace. Regional markets, long runs of standard products, and many of the tried and true ways of doing business are no longer applicable. We have entered an era of constant change and evolution. The challenge in this era is to make change a competitive weapon. We must learn to define, design, and implement the organizational changes required to adopt new technologies and new ways of doing business.

Global competition has raised the possibility of losing the industrial base from the shores of the United States. We can no

longer hold markets based on proximity, historical linkages, or traditional practices. Competition increasingly is based on the concepts of total quality, customization, and flexibility in industrial relationships as well as the product mix. Before discussing the technological issues and appropriate U.S. activity in these areas, let me first share with you some of the reasons why I believe the health of the U.S. manufacturing sector is critical to the health of the United States.

There is in this nation a dangerous willingness to draw analogies between the manufacturing and farm economies. That is, the United States was a farm economy some hundred years or so ago, and this economy employed ninety plus percent of our working population. Some have suggested that if the manufacturing sector were to go overseas, it would simply reflect the change from a manufacturing economy to a service economy much like the change that took place when we changed from a farm to a manufacturing work force. I strongly disagree! Losing the manufacturing economy to overseas competitors would be disastrous. Such a loss would not resemble the automation and retention of the farm economy which took place over the last century. The key word here is retention; that is, the U.S. still retains a significant farm economy. We have automated the farm so successfully that about three percent of the current population accomplish the work done by ninety percent of the population in the last century. In fact, those three percent are producing much more than was produced in the past.

It also is important to understand the scope of jobs that

are impacted by the manufacturing economy in the United States. Stephen Cohen and John Zysman in their book Manufacturing Matters make the important argument that twenty million jobs in the manufacturing economy are tightly linked to over forty million jobs in the service sector. Their point, simply put, is that if the United States were to lose the manufacturing sector, sixty million jobs would be lost. And, this loss occurs before one considers the usual ripple effects the loss of jobs can have on an economy.

Let's look more closely for a moment at the popular notion that we are in a transition from a manufacturing base to a service sector base with respect to jobs. If one then interprets this argument to mean we will automate the manufacturing sector while the bulk of the population moves into service sector tasks, there is important and strong evidence to the contrary. Dennis Swyt of the National Bureau of Standards has discovered some very important trends in the categorization of occupations for the United States. I will not repeat here the bulk of his analysis, but rather recommend that you invite him to testify on his work. Let me, however, summarize his findings as follows.

Swyt has grouped U.S. workers into four categories. (1) Engineering technical & professionals workers, (2) Production workers, (3) Management & administrative workers, and (4) Service sector workers. He then has categorized various industries by the mix of employees in each of these four categories -- and projected the future make up of the US work force over time. His results show that only one of the above categories (engineering technical and professionals) is growing at an increasing rate.

This finding is very important to the arguments I will make later regarding the importance of education to the new basis of competition. Let me say again that Swyt has other important results which I believe are relevant for this committee.

As I said before, we will not automate manufacturing and thus move to a service economy in the same way we moved to a farm economy. That is not to say that we will not use a great deal of automation in the manufacturing sector. For we will. Nor do I mean to imply that there will not be a shrinkage in the unskilled labor force employed in manufacturing. For again there will. We are now very successful at automating the "brawn" role of man in manufacturing. We have in fact moved beyond using technology to amplify the "muscle power" of the worker, and now we have turned to amplifying the "brain power" of the worker. We are expecting great strides in the development of more and more advanced tools for man to use in engineering, technical and professional tasks. Note the similarity with the predictions of Dennis Swyt. The technological developments in man-machine symbiosis are only beginning to appear, and innovative utilization of these tools will, in my mind, be the basis for competition in the future.

In discussing the importance of manufacturing to the United States, I must mention the role of manufacturing in support of the DOD. The frequency of change and increased utilization of technology in weapon systems has increased significantly the importance of manufacturing capability to the DOD. The capability of the US industrial base in both peacetime and in a national emergency for surge mobilization, etc., have been the focus of

much debate in other forums. Let me say that, in my mind, there is a deep and mutual dependence between the DOD and the manufacturing sector.

While there are other reasons that can be discussed, I hope I have at this point established why the health of the U. S. manufacturing sector is critical. I would now like to turn to the issues raised in my invitation to testify.

One factor necessary to improve the health of manufacturing is education. Manufacturing is becoming a highly technological field. Strong evidence in Dennis Swyt's paper and elsewhere indicates an increasing demand for engineering and technical professionals. Early evidence shows that we might not be turning out enough of these people from our universities and colleges. Nor are these individuals being sought after in numbers that seem appropriate to me. Should the awareness of this need reach the majority of employers, it is not at all clear that the academic system has either the capacity or expertise to turn out the volume of required professionals in the near term. Nevertheless, important strides are being made at Lehigh and at other institutions toward these objectives.

I would like to address your interest to the manufacturing Systems Engineering (MSE) Program at Lehigh University at this point. Our MSE program is rather unique with respect to normal graduate programs, both at Lehigh and at other universities. It is unique because:

It is interdisciplinary; the faculty who conceived of and operate the program represent three engineering departments and the college of Business and Economics.

The students enroll in one of six engineering departments and MSE. They represent a mix of disciplines and expertise which matches those required in modern manufacturing systems.

Half of the students are on leave from their companies at full salary and are assigned to Lehigh to earn an MS in MSE.

The program employs a mix of formal and informal learning and emphasizes teamwork and group assignments.

The program is highly structured, and it focuses on the manufacturing system life cycle and the systems' nature of modern manufacturing.

The goal of the program is to develop engineers who can design, install, operate and change manufacturing systems made up of people, machines, new materials, information systems, and appropriate technology.

Students and faculty work toward a high degree of interaction with industry. This is manifest in laboratory assignments, seminars, trips, and in the topics chosen for theses and special projects.

Applied research and development activity at Lehigh is a critical part of the MSE program as well as the basis for advanced and theoretical research which complements this activity.

Beyond being unique or special in the ways described above, we have been successful in the ways which count the most. Our graduates are running away with the placement records for highest number of offers and highest salaries offered.

Our customers include the industrial firms which send their

employees back to Lehigh and who hire our graduates. They recently joined with us to form an Advisory Board. The Advisory Board companies provide the critical mix of financial support, advice and guidance necessary to be successful in this type of program.

Together with the Advisory Board companies, the Lehigh faculty maintain the relevance of this program and focus on preparing our students to deal with the factory of the future. I will turn now from the details of our program at Lehigh to some remarks on the "Factory of the Future."

The factory of the future should not be thought of as separate from the rest of the enterprise in the future. The term computer integrated manufacturing (CIM) was invented for the factory of the future, and CIM began to be a popular acronym for describing advances to be made. More recently, however, the letters CIM have been redefined to mean "completely integrated manufacturing".

Thus, the factory of the future will be an integral part of the enterprise and have close connections with marketing & sales, engineering & planning, shipping & service, etc. In fact, it is safe to say that traditional organizational lines will change drastically as we define and organize the enterprise to meet a changing set of competitive factors and employ the new technologies.

With respect to technology transfer and applied R&D, the State of Pennsylvania has been a leader in this area with its Ben Franklin partnership program. Because the State uses its funds to leverage those of industry and has not used a crystal ball to

decide what research or development industry should be encouraged to follow, I find the program to be a very good one. A Pennsylvania company teams with an academic partner of its choice. Together they select a team project (for both industry and academic players) which will either transfer, develop or apply technology beneficial to the company. The state measures results in terms of jobs created or retained, new products, new processes, new patents, or other developments that strengthen the competitive nature of the company in Pennsylvania. Since its inception in March of 1983, the Ben Franklin Center at Lehigh has helped companies develop more than 400 new products or manufacturing processes.

This program has had benefits well beyond those measured by the state. It provides to the academic partners: A real perspective on the problems and constraints of industry; an opportunity for students to work on meaningful projects; and a test bed for their ideas and concepts for modern manufacturing. It provides to the industrial partners: an exposure to faculty, students, laboratories, equipment; and an air of excitement that manufacturing professionals have lacked in the past. In all, I would rate this program as win-win-win for the state, industry, and academia. It has been replicated and cloned by many other states -- some because they saw it in operation and some because they thought of it on their own -- and each such program has variations to suit individual needs. Missing are: (1) The complimentary programs which fund the establishment of centers of excellence with the requisite facilities; (2) Adequate funding

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for long-term basic research on an increased scale; and (3) Recognition by states and other funding agencies that we need a mix of technology transfer, applied R&D, and fundamental university research.

Thus, the NBS Hollings centers and the various industrial consortia being set up to fund technology transfer and applications development are important. However, they answer only part of the need.

In leaving the subject of technology transfer, let me summarize my feelings as follows. We are aware in the three communities -- academia, industry, and government -- of the challenge and the need before us. A variety of mechanisms to address the problem are being tested and more are coming into place. The focus seems to be on a partnership between academic institutions (including two year schools) and industry with the state and federal governments providing seed funds, equipment for sharing, and matching dollars where possible. Early results are encouraging and scale up seems to be taking place. New interest in helping small and medium size business is healthy, but care should be taken not to leave out the large businesses which are the backbone of the American industrial base.

Let me now turn to a focus on the general status of manufacturing systems research and development in the United States. These R&D activities have not traditionally been a high glamour area. Thus, we have had to overcome problems of inertia, and lack of interest. The advent of robots, computers, lasers, and other new technologies has helped to spark interest. However, industry has been slow to accept and utilize the new developments

and techniques. While much attention has deservedly been focused on the issues of technology transfer and organizational change, it is wrong to assume that adequate manufacturing R&D activity is taking place. R&D must be recognized as an important long-term investment. Not only is it imperative that we develop new and appropriate technology transfer mechanisms, but we must simultaneously nurture the R&D efforts that will be required as we "get our act together". As I mentioned before, there is appropriate awareness by funding agencies and industry of the need to fund applied R&D and technology transfer development. What is not adequately funded or planned is the required complimentary fundamental R&D efforts for the next generation of technological developments needed for the manufacturing enterprise.

We can subdivide the research issues into three broad categories: Traditional manufacturing components research, information and integration methodologies, and organizational and strategic research.

First, let's look at the traditional research into manufacturing processes and control, new materials, engineering methodology, and what is sometimes called the component technologies of manufacturing. In this area we have a long history of inertia to overcome. Handbooks, tables, methods and practices developed over the last forty years were based on assumptions no longer applicable. Thus significant improvements in control, modeling, simulation, and fundamental properties of materials and their transformation, until recently, have not been

attempted and were considered pushing the decimal point. Now that we are beginning to be able to use increased scientific understanding, the time lag and inertial problems of adapting to change are impediments to practice. Examples of this can be seen in the relative number of engineers in production facilities and the size and number of R&D laboratories addressing these subjects vis-a-vis some of our overseas competitors who were forced by circumstances to begin again, while we rested on existing capabilities.

The second research area, which we call the technologies of integration and information, is dependent on the micro & super computer developments, data bases, networks & communication systems, artificial intelligence, and new developments in computer science which permit order of magnitude increases in the information handling capabilities of computer integrated systems. This is perhaps the area of leadership still maintained by the United States, but it is no longer our exclusive province by any means. International and worldwide recognition of the potential benefit of progress in this area on industry is widely accepted. In fact, some difficulties arise because it is assumed that the benefits of this research area are so obvious as to not require planning, coordination or appropriate experimental design.

The third area of research is in organizational behavior and the ties between strategic and technological plans for industry. New measures, organizational structures, relationships between divisions and even with outside suppliers and customers are being investigated. This requires the integration of engineering and technical teams with those of business and management and is

having dramatic impacts where it can be accomplished. Impediments to research in this area include human factors, organizational inertia, and a general difficulty in recognizing the new era and its required changes.

In summary, the United States is leading in one of these three areas. We have advantages of size and historical leadership in computer-driven technologies, which perhaps afford us a leadership role in area two. The neglect of fundamental manufacturing technologies in the past has, in my opinion, put us in a catch up position in the first area with rare exceptions for various pockets of excellence. As for area three, I don't feel comfortable in assessing our research position vis a vie global competitors.

There are no fundamental reasons why the United States cannot be a leader in world class competition now and for the foreseeable future. This will however require changes in the way many companies do business, measure their operations, and choose their partners.

The federal government also has a very important role in R&D and beyond. Their role is to foster the health of the manufacturing economy out of enlightened self interest. Perhaps the biggest impediment the government places to progress is the lack of consistency (both consistency of a single policy over time and of one policy with an other) in its public policies. The lack of consistency and great public debate over changes in public policy which occasionally rage over years causes a wait and see or short term focus on decisions. Many of these delays

have an adverse impact on the long term perspective of the company.

There is a lack of focus as to which agency of the federal government has a mission or responsibility to handle the manufacturing issue. Thus new initiatives, guidance and support to various agencies are all difficult to accomplish. Obvious choices for an advocate include the DOD, Commerce, or developing a new agency. Having a government advocate would, I believe, be a major step forward.

Government reporting rules and regulations, standard accounting practices of the past, arbitrary regulations, etc. can in various ways be impediments to progress and competitiveness.

The federal government must take the lead in declaring education of U. S. citizens in engineering and technical professions as a national priority. Beyond an increased emphasis on these areas at the undergraduate level is the need for a priority at the graduate level as well. This must take the form of increased federal support for higher education in the form of fellowships, student loans, and other means of increasing the population of American students in our graduate schools. In addition, the government must end the practice of providing tax disincentives for graduate students on both a full- and part-time basis.

Perhaps most importantly, the government has a role in the organization of a research agenda and the funding of basic manufacturing science to complement the applied R&D and technology transfer activities. I have reviewed in various forms the R&D efforts of internal government agencies and their funding

plans. For the most part they remain uncoordinated and too small to make the impact required to restore and retain a successful competitive position for the United States. A mandate from Congress will help speed up the process and increase the effectiveness of government activities in manufacturing research and development.

Thank you for the opportunity to testify today. Given the time limit of ten minutes I have tried to keep my remarks general and to avoid the specific facts, figures and examples which would draw my testimony well beyond the time limit. I will be happy to answer questions and amplify on my remarks at your convenience.

Mr. ROE. Thank you, Dr. Nagel. Mr. Kramer.

STATEMENT OF SAMUEL KRAMER, DEPUTY DIRECTOR, NATIONAL ENGINEERING LABORATORY, NATIONAL BUREAU OF STANDARDS

Mr. KRAMER. It is a pleasure to appear before the Committee to describe the National Bureau of Standards program in automation and in particular the program being conducted at our Automated Manufacturing Research Facility. With your permission, I would like to submit my prepared statement for the record, and summarize the remarks; and hopefully then respond to questions.

Before I start my comments, I would like to say that the Bureau of Standards has always, in the National Engineering Laboratory, stressed the importance of quality control and interacting with industry and in tech transfer. By coincidence, Dr. Nagel, who just testified, I would like to note, we have had the privilege of having him with us for a few years in the very early stages of the formation of our automation program. Dr. Nagel contributed significantly, and then left us to join Lehigh, and if I may say so, Roger represents one of our better tech transfer efforts. And we still maintain a very close collaboration of working between Lehigh and the Bureau.

Another thing is, I might note, I did my homework before coming to see who the other witnesses were, to note that Eastman Kodak Company, and Air Products, both corporations at many levels, but including from their CEO's, are participating with the National Bureau of Standards, and in particular in our latest effort, the Malcolm Baldrige Quality Award,[3] in trying to recognize industry and encourage it. So we thank those corporations for their contributions. But more, I would like to point out they merely exemplify what we consider to be a very important role for the Bureau and that is to be in continual dialogue with industry and academia and not to operate our program in isolation from them. I guess if I end there, it would be the best part of my testimony.

The Automation Program at the Bureau is part of a coordinated NBS technical effort to support U.S. industry's improved productivity, quality control, and international competitiveness. It began in the 1970's with research on robotics and development of computer-controlled coordinated measuring machines. In the 1980's, we first introduced the twin concepts of an Automated Manufacturing Research Facility [AMRF] and a plan, a definite plan for transferring advanced manufacturing technology to American industry, especially the small and medium-sized manufacturers.

We have completed the construction of the initial AMRF. The facility operates now under a computer control system using advanced control approaches pioneered at NBS. In December, 1987, we demonstrated its ability to perform and at that one run alone we had over 500 people from industry, academia and other Government agencies participate. To date, we had over 70 research associates representing about 40 companies and Government agencies who have worked alongside the NBS staff in the activity. In addi-

[3] The Baldrige Award was established by Public Law 100-107, the Malcolm Baldrige National Quality Improvement Act of 1987. It commemorates the late Secretary of Commerce.

tion, we have been affiliated with about 50 universities in various forms of research. Industry's commitment in this program, I think, can be displayed by 36 companies who have loaned or donated equipment at a value of over $5.7 million to the National Bureau of Standards' AMRF, and that equipment operates in our facility with our research.

The AMRF is a unique engineering laboratory in that it provides a basic array of manufacturing equipment and systems, a testbed that researchers from all sectors use and experiment with—experiment with new standards and study new methods of measurement and quality control for automated manufacturing.

The AMRF incorporates some of the most advanced and most flexible automated manufacturing techniques in the world. NBS is the Nation's primary laboratory for measurement science and engineering, and has two principal goals for its automated manufacturing program: to supply the industry with new ways of making precisely machined parts—with dimensions that can be referenced to the national measurement standards—and to encourage the modernization of American manufacturing by providing the technical information necessary to develop standardized interfaces between various types of equipment.

The National Bureau of Standards is also using this testbed and will do so even more as the testbed for research on the next generation of "knowledge-based" manufacturing systems—automation systems that incorporate artificial intelligence capabilities.

Let me go back a little bit, historically. Manufacture and measurement have always been two separate processes. A machinist would cut a part on a milling machine and stop periodically to check dimensions with calipers and gauges. As manufacturing techniques became more and more efficient, the measurement part of the operation consumed an even greater percentage of the time required to produce a part. The development of the automated coordinating-measuring machine in the 1970's helped somewhat, but measurement still used up about 50 percent of the total time required to produce precision parts.

It would be many times more efficient if the machining process could be made to produce accurate parts without being interrupted by the measuring processes. Not only would it take less time, but fewer parts would have to be scrapped for being out-of-tolerance.

Some surveys have shown that in some cases one-third of the work force is engaged in either rework or correcting out-of-tolerance parts.

The National Bureau of Standards research suggests that the program can be solved by use of today's computer-controlled machine tools, because the position of the cutting edge of the tool is known and controlled at all times, at least in theory, by the computer. The computer could then be programmed to compensate for known errors in the machine's movement, using sensors that feed back information on the machine's condition.

The concept of feedback and process control is well known in some industries, such as oil refining and chemical production. In discrete parts manufacturing, however, it will require the development of a whole new generation of sensors and control systems.

Now, this is not just theory, because NBS researchers have already applied some of these ideas to commercial machine tools and improved their performance in terms of accuracy and control five to tenfold. Some of this research already is finding its way into the marketplace.

If I may note one thing, and it was not in my talk. As an example of it, is a major project that is going on in the AMRF in what we call the Mare Island Work Station, which is being performed for the Navy. The Navy has a problem in producing what I call RESIC parts. It stands for "Resident Enabling Sound Isolating Connectors," that are used in nuclear submarines. It is a very precision machine part. It comes in about 40 different sizes and shapes. It is made up of a special material that is extremely hard to machine. Currently, these parts must be machined on order as the submarines come in for rehab, and it takes approximately 17 hours to make a part.

We are jointly working with the Navy, with NAVSEA, with Warner-Swazey, with Westinghouse. Two industrial companies have developed what we call the Mare Island Work Station. It has been set up at the Bureau of Standards. The part that took 17 hours to produce is now being produced on demand in 20 minutes.

We will run this machine, producing the parts for the Navy—it is anticipated that this one work station will be able to supply the parts of the entire Navy, and they even anticipate that the capital funds expended on it when it goes into full operation will be recovered in less than 2 weeks. This fall, if it is successfully run, we will then pack up the machines because we are not in the manufacturing mode, transfer it to Mare Island, CA, turn it over to the Navy for full operation. And we will already take off—we have in mind another project for them. I might say though, the result of this while it is going to DOD to the Navy, already the private sector is aware of it, we have tremendous interests from private machine tool manufacturers and others. We are looking to the transfer of this type of technology to the private sector. We are quite proud of it, and we hope it exemplifies some of the tech transfer.

The future for the manufacturing automation or robotic effort appears to be just as interesting as the past, as I noted. The AMRF will be used to do more research on automation, and we will also use it as a working research facility for tech transfer.

We expect to have an increase in collaborations with the private sector as our work becomes more directly applicable to the factory floor, and as industry becomes more automated. Based on the belief that this technology must diffuse rapidly if the nation is to compete internationally, we plan to continue to give priority to our efforts to transfer this technology to industry; we will look for more research associates and visiting scientists. We will make more videotapes, give more talks and write more articles. We continue to seek efficient ways to move the technology to small firms through intermediaries. Intermediaries are extremely important to us—intermediaries such as equipment vendors, trade associations and professional societies.

The National Bureau of Standards views technology transfer as an inherent part of our research program. Our Organic Act cites our responsibility to support the U.S. industry, and this aspect is

built into all of our programs in the National Engineering Laboratory. For example, in addition to the previously noted AMRF activities, we conduct seminars and training sessions, we present talks to the private sector groups, academia, professional societies and participate in numerous standards committees. In fact, Roger mentioned Dennis Swyt. I don't think Dennis is home, he is on the road with industry all the time, for the one reason, it is important we get the feedback from them as much as they know what we are doing.

The intensity of interactions can be exemplified by the seven runs that we had on the AMRF in which there was over—almost 4,000 participants from outside the Bureau participating in these demonstrations.

Our program addresses technological issues with a view to increased U.S. productivity and competitive positions in the complex world marketplace. However, we cannot do it alone. The cooperation and support of all parties in the public/private sector, academia and all other government agencies are essential if we are to be successful in this effort.

I would like to stop there, and then if there are any particular questions try to respond to the committee, et cetera.

[The prepared statements of Mr. Kramer and Mr. Lyons follow:]

U.S. DEPARTMENT OF COMMERCE

STATEMENT OF SAMUEL KRAMER, DEPUTY DIRECTOR

NATIONAL ENGINEERING LABORATORY

NATIONAL BUREAU OF STANDARDS

BEFORE THE HOUSE COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY

SUBCOMMITTEE ON INVESTIGATIONS AND OVERSIGHT

JUNE 27, 1988

Mr. Chairman and Members of the Subcommittee:

It is a pleasure to appear before this Committee to describe the National Bureau of Standards (NBS) program in automation and in particular the program being conducted at our Automated Manufacturing Research Facility (AMRF). I will also describe some of our technology transfer activities which are focused on advanced manufacturing technology.

The Automation Program at the National Bureau of Standards' National Engineering Laboratory is part of a coordinated NBS technical effort to support U.S. industry's improved productivity, quality control, and international competitiveness. It began in the 1970s with research on robotics and the development of a computer-controlled coordinate measuring machine. In 1980 we first introduced the twin concepts of an Automated Manufacturing Research Facility and a plan for transferring advanced manufacturing technology to American industry, especially to small- and medium-sized manufacturers. The foci of these activities were brought together in 1981 with the formation of the Center for Manufacturing Engineering.

We have completed the construction of the AMRF. The entire facility now operates under computer control using an advanced control approach pioneered at NBS. This capability was successfully demonstrated in the December 1987 public test run to over 500 people from industry, academia, and government. To date, over 70 research associates representing about 40 companies and government agencies have worked alongside NBS staff at the AMRF. In addition, we have been affiliated with about 50 universities in the forms of sabbatical research arrangements, and postdoctoral and thesis research. Thirty-six private sector companies have loaned or donated equipment, tooling, and software for use in the AMRF totaling over $5.7 million. The AMRF is but one facility (albeit a large one) in the overall automation program at NBS.

The automation program is carried out within the NBS National Engineering Laboratory which also conducts research in opto-electronics (photonics), the subject to be addressed by the next panel appearing before this Committee today. We had an opportunity recently to appear before another Subcommittee of the House Committee on Science, Space and Technology to present testimony on photonics. We believe that the testimony presented at that hearing is pertinent and would like to present it to your Committee for the record.

I will now discuss, in some detail, our automation and technology transfer activities. In the following sections I will present answers to some of the most common questions asked about the AMRF.

What is the AMRF?

The AMRF is a unique engineering laboratory at the NBS Center for Manufacturing Engineering. The facility provides a basic array of manufacturing equipment and systems--a "testbed" --that researchers from NBS, industrial firms, universities, and other government agencies can use to experiment with new standards and to study new methods of measurement and quality control for automated factories.

The AMRF includes several types of modern automated machine tools, such as numerically controled (NC) milling machines and lathes, automated materials-handling equipment (to move parts, tools, and raw materials from one "workstation" to another), and a variety of industrial robots to tend the machine tools.

The entire facility operates under full computer control. The AMRF incorporates some of the most advanced, most flexible automated manufacturing techniques in the world.

Why has NBS built this facility?

NBS, as the nation's primary laboratory for measurement science and engineering, has two principal goals for its automated manufacturing program: to supply American industry with a radically new way of making precisely machined parts--with dimensions that can be referenced to national measurement standards maintained by NBS--and to encourage the modernization of American manufacturing by providing the technical information necessary

to develop standardized "interfaces" between various types of equipment.

NBS also is using this facility as a testbed for research on the next generation of "knowledge-based" manufacturing systems -- automation systems that incorporate artificial intelligence capabilities.

Who supports this research?

In addition to NBS funding, the Navy's Manufacturing Technology Program is a major source of support. Several private firms and universities also contribute to AMRF research through the donation or loan of equipment or by providing personnel through the NBS Research Associate Program. The AMRF is an example of what can be achieved when industry, government, and academe cooperate.

What is this "new way of making precise parts"?

Historically, manufacture and measurement have always been two separate processes. A machinist would cut a part on a milling machine and stop periodically to check dimensions with calipers and gages. As manufacturing techniques became more and more efficient, the measurement part of the operation consumed an ever-greater percentage of the total work required to produce a part. The development of automated "coordinate-measuring machines" (CMMs) in the 1970s helped somewhat, but measurement still used up about 50 percent of the total time required to produce a precision part.

It would be many times more efficient if the machining process could be made to produce accurate parts without being interrupted by the measuring process. Not only would it take less time, but fewer parts would have to be scrapped for being out-of-tolerance. (Some surveys have shown that in the U.S. one-third of the work force in manufacturing industries is engaged in re-work--correcting out-of-tolerance parts.)

NBS research suggests that problem can be solved by use of today's computer-controlled machine tools, because the position of the cutting edge of the tool is known and controlled at all times, at least in theory, by the computer. The computer can be programmed to compensate for known errors in the machine's movement, using sensors that feed back information on the machine's condition.

This concept of feedback and process control is well known in some industries, such as oil refining and chemical production. In discrete parts manufacturing, however, it will require the development of a whole new generation of sensors and control systems.

This isn't all just theory. NBS researchers have already applied some of these ideas to commercial machine tools and improved their performance in terms of accuracy and control five to ten fold. Some of this research already is finding its way into the marketplace in new industrial machine controllers.

What is the importance of "standardized interfaces"?

Economics. The automated "factory of the future" offers American industry an important weapon in the highly competitive world marketplace, but even for the largest firms the lack of agreed-upon standards for "interfacing" complex equipment is a difficult--and costly--problem. For close to 90 percent of the discrete parts industry--about 100,000 firms--the problem is worse. These are much smaller companies (fewer than 50 employees) without great financial resources. Discrete parts producers, those who make products in small batches, are responsible for about 75 percent of the total U.S. trade in manufactured goods. These smaller companies need to be able to buy automated machinery in stages, one or two machines at a time, and slowly build up to an integrated system. They need the flexibility to buy from different manufacturers at different times with the assurance that the machines they buy will work together properly without a lot of expensive, custom-designed interfaces. They need the same flexibility that one can now find when buying the parts of a home stereo system from several different manufacturers, knowing that they will all plug together.

These firms also need a system flexible enough to switch from the production of one part to another quickly and without expensive reprogramming. These are mostly problems of standardization--standard procedures, standard protocols, standard interfaces. The challenge is to develop standards which support current technology and yet still encourage equipment manufacturers to develop new and innovative products. These are problems that NBS is studying in the AMRF.

Will NBS set these standards for the industry?

No. NBS is not a regulatory agency, and does not set standards, at least in the legal sense. However, NBS has a long history of working as a neutral, third party, providing technical knowledge and leadership and encouraging the establishment of standards. NBS research has become the basis for many standards adopted by private industry on a voluntary basis.

Three industrial standards have already been developed based on NBS automation research. For example, a standard method for exchanging graphics data between otherwise incompatible computer-aided design (CAD) systems, developed by a government-industry coalition led by NBS, was adopted by the American National Standards Institute (ANSI), a private voluntary standards organization. The standard now is supported by nearly all U.S. CAD vendors.

In the near future, the AMRF will be used as a "testbed" to assist a joint industry-government project to develop the Product Definition Exchange Specification (PDES), the next generation of data interchange standards for automated manufacturing.

AMRF research also led to standards for the characterization of computerized coordinate measurement machines, and for a method of surface texture measurement. Seven other potential standards are now being considered by various industrial standards groups.

What makes the AMRF unique?

Several things, including:

Its location at the National Bureau of Standards. As an open federal laboratory with no commercial interests, NBS makes this facility accessible to private firms interested in automation research--firms that individually could not afford such a complex research facility. NBS has a long history of working with private firms and organizations to develop standards and measurement and test methods that benefit the entire industry.

The active participation in the AMRF by industry, universities, and other government agencies. The AMRF has become a focal point for interactions among all American researchers in automated manufacturing.

The use of a wide variety of commercially-available machine tools and robots. Most other groups are interested in building new hardware; we have concentrated on software and communications.

The flexibility of the system. One of the goals of the AMRF is to create a facility that is, in the jargon of the researchers, "data driven" --the actions of the various machines and robots should be determined primarily, or solely, by a computerized description of the part to be manufactured. This stands in contrast to modern "flexible manufacturing" cells which are truly flexible only for a limited "family" of parts for which the machine tools are programmed.

Sensory interaction. The AMRF makes use of an unusually versatile

control system in which sensory information from, for example, the robot vision system is fed back to the controller to provide a basis for its decisions. This is important because it enables the system to react to its environment, eliminating the need for a lot of rigid programming.

The scope of the facility. Research at the AMRF covers everything from the preparation of data on a new part to final automated inspection.

Is the AMRF a prototype?

No. The AMRF is not a prototype of the "factory of the future." It is extremely unlikely that any actual factory would resemble the AMRF, at least physically. The AMRF is a laboratory for studying factory automation. It also demonstrates several new and potentially important techniques for machine control and the integration of diverse systems, the completed AMRF will not be a museum piece but rather a working research facility.

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The future for the manufacturing automation and robotics effort appears to be just as interesting as the recent past. As noted above, we completed the building of the AMRF. The AMRF will now be used as a working research facility for technology transfer. It will also be used as a "testbed" to assist a joint industry-government project to develop the Product Definition Exchange Specification (PDES), the next generation of data interchange standards for automated manufacturing and for further development of Computer Aided Process Planning, Manufacturing Data Models, and Data

Administration Systems. With the installation of a diamond tool turning center, we have begun to address such research questions as diamond tool properties and the accuracy enhancement of the machine by computer control at the sub-microinch (.025 micrometer) level.

We expect increasing collaboration with the private sector as our work becomes more directly applicable to the factory floor, and as industry becomes more automated. Based on the belief that this technology must diffuse rapidly if the Nation is to compete internationally, we plan to continue to give priority to our efforts to transfer this technology to industry; we will look for more research associates and visiting scientists, make more videotapes, give more talks, and write more articles. We continue to seek efficient ways to move the technology to small firms through intermediaries such as equipment vendors, trade associations, and professional societies.

NBS views technology transfer as an inherent part of our research program. Our Organic Act cites our responsibility to support industry--this aspect is built into all of our programs in the National Engineering Laboratory. For example, in addition to the previously noted AMRF activities, we conduct seminars and training sessions, present talks to private sector groups, academia, and professional societies, and participate in numerous standards committees. The intensity of these interactions is exemplified by the seven public demonstrations we have conducted on the AMRF attended by about 4,000 visitors including Congressmen, Senators, and Congressional staff.

The Administration, Congress, the public and private sector are all

concerned with the health of the U.S. industrial sector and the overall economy. Our programs address technological issues with a view to increased U.S. productivity and competitive positions in the complex world marketplace. The cooperation and support of all parties are essential if we are to be successful in this effort.

This concludes my prepared statement. I will be glad to respond to your questions.

SAMUEL KRAMER

Date of Birth: June 2, 1928

Birthplace: New York City, New York

Professional License: Registered Professional Engineer (P.E.)

Position:
Deputy Director
National Engineering Laboratory
National Bureau of Standards

Since January 1981, Mr. Kramer has served as Deputy Director of NBS/National Engineering Laboratory with responsibilities in the management of the Laboratory's overall programs. These programs are concerned with research in electronics and electrical engineering, automation, manufacturing engineering, building technology, fire, energy conservation, chemical engineering, engineering standards development, applied mathematics, and scientific computing.

From March to December 1983, Mr. Kramer served as the Acting Director of the NBS/National Engineering Laboratory.

In March 1978, Mr. Kramer was appointed the Associate Director for Program Coordination of the NBS/National Engineering Laboratory with responsibility for the coordination, monitoring of programs with outside organizations, other Federal agencies, state and local governments, international bodies and industry.

In July 1970, Mr. Kramer joined the National Bureau of Standards as the Federal Building Research Program Coordinator in the Institute for Applied Technology's Building Research Division. In July 1972, when the Center for Building Technology was formed at the National Bureau of Standards, Mr. Kramer was appointed Chief of the Office of Federal Building Technology. From September 1974 to September 1977 he served as Acting Deputy Director, Center for Building Technology. In September 1977 he assumed the position of Chief, Office of Housing and Building Technology with responsibilities for management of the Housing, Federal Building and Energy Conservation Programs.

He served in the Bureau of the Budget, now the Office of Management and Budget, Executive Office of the President for over four years. Mr. Kramer had responsibilities in a number of major program areas, including the environmental quality programs, the Federal Water Quality Control Administration of the Department of the Interior, the Tennessee Valley Authority, the Panama Canal and interstate and Federal-interstate compacts.

Mr. Kramer was in the private construction industry before joining the Corps of Engineers, where he served as a civilian engineer for 10 years. At the Corps of Engineers, Mr. Kramer was responsible for the development of design criteria and the design and construction of military projects throughout the United States. He received 12 citations and awards from the Corps for outstanding engineering.

Mr. Kramer was in the military service from September 1950 through August 1953, during which he served as a battalion staff officer with an engineering construction battalion responsible for the construction of major facilities in Europe.

Mr. Kramer is a graduate civil engineer and has done graduate study in the field of public administration. He is a registered professional engineer (P.E.) and is a member of the American Society of Civil Engineers and the National Society of Professional Engineers. He was elected to Tau Beta Phi and Chi Epsilon, National Honorary Engineering Organizations. He is the recipient of numerous awards and honors including the Department of Commerce Silver Medal and the SES Meritorious Rank Award. He is active in community, educational, and religious organizations.

U.S. DEPARTMENT OF COMMERCE
GAITHERSBURG, MD 20899
STATEMENT OF
JOHN W. LYONS, DIRECTOR
NATIONAL ENGINEERING LABORATORY
NATIONAL BUREAU OF STANDARDS

BEFORE THE

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY
ON
PHOTONICS

I am pleased to be here this morning to discuss with the Subcommittee the area of technology called photonics, often also referred to as optoelectronics, lightwave technology, or optical technology. In the early part of this decade the National Bureau of Standards conducted a study of this sector to see what new services were needed by U.S. industry. The result was the launching of a new program intended to provide industry with the needed new information. I summarize here what we learned and why we became convinced we needed to do much more.

Photonics is signal processing using beams of light. (Electronics is signal processing using currents of electrons.) Strictly speaking, all of the component parts of a photonic system operate using only light. Such systems are rare; most commercial applications are in fact hybrids of photonics and electronics. Hence the term optoelectronics. There are many differences between the two kinds of signal processing. The commercial motivation for moving to photonics is primarily the much greater processing rate for information afforded by photonics.

We found that the technology affects primarily three major fields of application: communications, computing, and sensors. The commercial impact is, for the next decade and perhaps longer, clearly greatest in communications. In fact the telecommunications industry has been installing fiber optics lines as rapidly as the fibers can be manufactured and signal processing using light is now a very substantial part of long distance communications. Before discussing the communications application let me say a few words about the other two areas.

The motivation to use light waves in computing arises from three advantages: switching speed, information capacity, and freedom from electromagnetic interference. Optical switching speeds are as much as a thousand-fold faster than electronic switching - the former operating in as short a time as a few femtoseconds (quadrillionths of a second) and the latter operating at picoseconds (trillionths of a second). The information capacity is larger in part because the systems operate faster but also because in some applications the information can be processed in parallel streams. Consider image transmission and manipulation. To process an image electronically the image is divided into very small subdivisions (usually called pixels) and the information averaged over the pixel. This information is then transmitted pixel by pixel sequentially over the electronic circuit and reassembled at the receiver. This is one-dimensional processing. In contrast, optical systems can gather information from an image all at once, pass it through lenses, thence down a fiber, and enlarge the image at the receiver. Adding the capabilities of holography permits three-dimensional information to be moved

about in a parallel manner. The increase in capacity is enormous. A major part of the research in optical computing is related to image analysis.

Other potential applications of photonics in computing are fast linkages between and within computers. It is already common to connect computers with optical fibers; we do this today at the Bureau. There is research in progress in many laboratories to connect the internal components of computers either through fibers or by simply beaming light through space from one chip to another. Such techniques offer promise for three-dimensional architectures within individual chips as well. It is our impression that there are some technical barriers that must be overcome before optical computing can be applied widely. Two of these are the difficulty of miniaturizing to the same degree as is now possible with silicon integrated circuits, and the relatively high power requirements to drive the light sources. There also remains a good deal of materials development in non-linear crystals before full advantage can be taken of optics in logic components.

A related market is that for optical storage devices. The technology already exists for storing and reading digitized information on disks. They are called optical systems because of the use of laser beams to record the information on the disks and laser beams to read it from the disks. Commercial examples of this are video disk players and compact disk (CD) audio systems. The devices use electronic processing for all but the write and read beams and are therefore optoelectronic systems. The Japanese made an all-out push in the consumer markets for these systems and thereby learned a great deal about how to manufacture high-quality, low-cost solid state lasers. It is this

technology that has given the Japanese a competitive edge in lasers for telecommunications systems (see below). Optical storage systems for computers are emerging now and should become a substantial market. The advantages are in the high storage capacity compared to conventional disk storage. Most current systems are read-only or write-once technology but just recently read-write systems have been announced. They permit erasure or write-over as is now the case for magnetic systems.

Sensors based on optical signal processing are not new but there are some new opportunities presented by the availability of very good fibers to serve as sensors themselves in some cases and to carry signals from the point of sensing to the signal processor. For example a magnetic field rotates the polarization of light in some materials; the stronger the field the more the rotation. Since the strength of the magnetic field around a wire varies directly with the amount of electricity flowing in the wire, this optical rotation can be used indirectly to measure the flow of current. Discovered by Michael Faraday 150 years ago, the effect has not been used commercially until the advent of optical fibers and optical signal processing. NBS now has programs to provide measurement services based on such optical sensing systems. There are fiber optic sensing systems to serve as gyros in navigation systems, to measure pressure variations in the ocean, to measure electric fields, temperature by several techniques, and acceleration for such uses as detecting seismic disturbances. Such systems are not likely soon to become a major economic factor in themselves but the systems will facilitate higher efficiency and improved quality control in many industrial sectors and will be very useful in military and medical technology.

Turning now to the major application - telecommunications - I first note that the value of telecommunications services sold by U.S. firms is reported by the U.S. Department of Commerce to have been $128 billion in 1987 rising to $138 billion in 1988. The hardware shipments from U.S. companies - switches, microwaves systems, military devices, and commercial systems was valued at $52 billion in 1987. About half of this went for civilian systems, half for military. The recent move to optical communications systems is reflected in U.S. purchases of about $1 billion in fiber optic components in 1987 and a worldwide market for these components of about $2.5 billion in 1988. An independent forecast for the world market for optical systems and components is for growth to about $12 billion by the year 2001. This figure compares favorably with the figure of about $10 billion for electronic equipment in the same marketplace today. There is no question but that the telecommunications market is one of the largest sectors of the U.S. economy and its health has a significant bearing on the overall state of our economy. Before commenting on the relative positions of U.S. technology and that of our competitors, I shall first discuss the nature of optical communications systems.

During the last twenty years technologists have learned how to make glass fibers capable of carrying pulses of light over very long distances without distortion or significant losses. This development meant that we have the equivalent of a copper conductor for light beams. The advantage is that the fiber can carry much more information than a copper wire and is much smaller and lighter. The communications industry saw the advantage immediately and began intensive commercial development of these optical communications systems.

As soon as the first generation of these was available the industry began installing them and has been doing so ever since as fast as the fiber and components can be manufactured.

The optical fiber is the pipeline for the signals. The system requires a number of components. First the information to be transmitted must be converted into pulses of light. This requires a light source, now typically a solid state laser based on modified gallium arsenide semiconductor material, and a means to convert its output into pulses that represent the digitized form of the information. We call this component the modulator. If the length of transmission is longer than one length of fiber can carry then we need a means to acquire the pulses and retransmit them. At the receiving end of the fiber we must have devices that detect the pulses and convert them back into the original information form - a detector and a demodulator. Because the fiber has such an enormous capacity for pulses compared to the size of any single stream of information we want to send many streams at once. Devices to mix the streams together and then, at the other end, separate them, are known as multiplexers and demultiplexers. And, finally, if we need to pass through junctions and route signals in many different directions we need switches.

Today's technology accomplishes all of the above functions using discrete components. Most of the commercial systems use electronic devices to modulate and switch the optical signal. Therefore the technology is not truly photonics but optoelectronics - a blend of technologies. The rate at which data can be processed is limited not by the capacity of the optical fiber but by the rate at which the electronic components function. The fibers can actually handle a

thousand times more than can now be supplied to them. Subsequent generations will have more optical components, less electronic types and will combine functions on single devices integrated much as electronic chips are today.

NBS provides measurement services for optical fibers and for lasers. These are reflected, for example, in some 25 voluntary industry standards on fibers for such properties as attenuation, dispersion, numerical aperture and the like. We are developing additional services for the other components of these systems beginning with sources, detectors, and planar waveguides. We have begun work this year on modulators, demodulators and couplers, and expect to begin work in 1990 on multiplexers, demultiplexers, and switches.

Our relationships with Japanese technologists in this field are very good. In 1984, as part of high-level negotiations between the U.S. and Japan concerning opening the Japanese telecommunications market NBS signed a research agreement with the Nippon Telegraph and Telephone Corporation (NTT). One of our researchers recently was awarded the NTT Research Director's prize for a joint project on fast sampling the output of solid-state lasers. We think we understand the relative state of technology here and in Japan. Technology for optical fibers is roughly on a par in the U.S. and Japan. Both countries are manufacturing and installing high quality fibers as fast as they can. The Japanese seem to us to be ahead in a commercial sense for the components, for example light sources (laser diodes). This is not to say the Japanese are ahead in the laboratory but rather that they have decided to market the components as needed and not wait for the next generation. U.S. companies seem often to be holding back, perhaps because the technology is evolving rapidly.

The leading U.S. research, for example at AT&T Bell Laboratories, continues to hold an edge although it is difficult to stay out in front of the Japanese in this field. European and Canadian technology is strong.

NTT has been aggressively exploring applications for optical systems. It has, for example, installed optical lines in a local telephone exchange directly into homes and then experimented with a number of new information services to those homes. They report that the homeowners did not in all cases react with enthusiasm. But this experience is indicative of the NTT desire to exploit wherever possible the expanded information capacity of the optical technology.

This concludes my testimony. I shall be happy to answer any questions the committee may have. Thank you, Mr. Chairman.

JOHN W. LYONS

Date of Birth: November 5, 1930

Birthplace: Reading, Massachusetts

Education: Degrees
Harvard University, A.B., Chemistry - 1952
Washington University, A.M., Physical Chemistry - 1963
Washington University, Ph.D., Physical Chemistry - 1964

Position:
Director
National Engineering Laboratory
National Bureau of Standards

As Director of the National Engineering Laboratory, Dr. Lyons is responsible for NBS's research in applied mathematics, building technology, electronics and electrical engineering, energy conservation, engineering standards development, fire, manufacturing engineering, and chemical engineering.

From April to December 1983, Lyons served as the Acting Deputy Director of the National Bureau of Standards.

As Director of the NBS Center for Fire Research until December 18, 1977, he was responsible for providing scientific and technical knowledge applicable to the prevention and control of fires.

Lyons served in various research and development positions at the Monsanto Company from 1955 to 1973. He specialized in the chemistry and uses of phosphorus-based chemicals including fire retardants. He served from 1971 to 1973 as a member of the ad hoc panel of fire research, a National Academy of Sciences evaluaton panel for the National Bureau of Standards.

He is author of three books: *Viscosity and Flow Measurements, The Chemistry and Uses of Fire Retardants,* and *Fire.* He was co-author and editor of Fire Research on Cellular Plastics. He has contributed chapters to five other books and has written numerous papers and articles on technical or research topics. His early research interest was the physical chemistry of polyelectrolyte solutions, especially formation of complexes with metal ions. This work emphasized the behavior of inorganic polyphosphates and desoxy ribonucleic acid (DNA).

Lyons is a member of the National Academy of Engineering, a Fellow of the American Association for the Advancement of Science, a Fellow of the Washington Academy of Science, a member of the Naval Research Laboratory Naval Research Advisory Committee, a member of the Office of Science and Technology Policy Committee on Federal Laboratories, member of the American Chemical Society (past chairman of the St. Louis Section) and member of Sigma Xi. He serves on the Advisory Committee for Engineering, National Science Foundation; Advisory Council, College of Engineering, University of Maryland; Board of Directors, National Fire Protection Association and Board of Directors, American Society for Testing and Materials. He served on a special committee of the Maryland State Board for Higher Education to study the needs for engineering education (1983-84). He was chairman of the Products Research Committee (1974-79), a nine-member charitable trust administering a $5M research fund on fire research; co-chairman of the US-Japan Natural Resources Panel of Fire Research (1975-78). He received the Presidential Management Improvement Award in 1977 and the US Department of Commerce Gold Medal, also in 1977. In 1981 he received the Presidential Rank Award of Distinguished Executive. He received the Edward Uhler Condon Award in 1986 for the book *Fire.*

Mr. ROE. OK, thank you. Our next witness is Mr. Francis W. Jackson, director of quality management planning for Eastman Kodak. Mr. Jackson.

STATEMENT OF FRANCIS W. JACKSON, DIRECTOR, QUALITY MANAGEMENT PLANNING, EASTMAN CHEMICALS DIVISION, EASTMAN KODAK CO.

Mr. JACKSON. Thank you, Congressmen Roe and Ritter. The Eastman Chemicals Division, a division of Eastman Kodak, has a proud history of meeting customer needs with products and services that are high in quality and value. However, we recognize that quality that was good enough yesterday may not be good enough for today. Likewise, products that meet today's quality standards will not meet tomorrow's requirements. Therefore, the Eastman Chemicals Division is taking aggressive measures to continually improve the quality of its products and services.

Eastman Chemicals Division produces most of its products in a large number of diversified processes with highly integrated material flow at four major U.S. plant sites, and operates several U.S. and offshore plants. Total employment is approximately 16,350. In addition to the four major U.S. manufacturing sites, Eastman ECD has a research and development organization, a marketing organization, and six business centers. We are managed through a matrix of functional line organizations and business centers organized by product streams or special end-use products. ECD is primarily a supplier to industrial customers. Our goal is to satisfy customers by being the leader in product quality and value on the basis of fitness-for-use and consistency, as well as the leader in product value on the basis of being the best choice for competitive cost combined with superior reliability, technical service, customer service, and knowledge of the markets in the customer/supplier relationships. We strive to be an exemplary corporate citizen concerned about our employees, the environment, and the communities in which our operations are located.

Eastman Chemicals Division is achieving excellence and meeting tomorrow's challenges by effectively using quality management principles. Quality management is being used at all levels and in all functions of the organization as a system for managing our business. ECD is achieving its mission and vision through the broad application of a quality control and improvement model. By doing this, we are attaining our quality goal—to be the leader in product quality and value.

The Eastman Chemicals Division started the implementation of quality management concepts as a result of losing market share in a major product in the late 1970's. The strategy that was used to regain the market share focused on improving quality of products as well as improving the quality of the management of our processes. The result of this effort allowed us to regain our market share position but, more importantly, demonstrated that focusing on improving quality also yields improvements in productivity and reductions in manufacturing costs. Our successful experience in the application of quality management concepts resulted in a massive

management-led project to implement quality management concepts in every aspect of managing the Eastman Chemicals Division.

This journey began with the development of the Eastman Chemicals Division Quality Policy. This document establishes the quality goal of ECD to be the leader in product quality and value. In addition to the quality goal, the policy outlines our management principles and key elements that guide the development and application of management processes throughout the organization. A primary management principle is continual improvement. We must never be satisfied with our current level of performance. We achieve improvement through two distinct and essential processes. First, through the routine control of processes, we will continually achieve improvement by identifying and permanently removing the causes of deviations from the desired levels. This process utilizes current resources allocated for operations. Second, a further improvement process consists of allocating special resources to bring about major shifts in the desired levels. This improvement process may require new and improved technology. It is essential that all resources be properly allocated to achieving continual improvements.

Our second management principle is defect prevention. Defect prevention is achieved through job design, procedures, and process control. This principle ensures consistency in our routine operations resulting in high quality, defect-free products and services.

The ECD operational policy, a component of our Quality Policy, gives top priority to establishing process capability and controlling every process to the desired target within the process capability. This has resulted in ECD defining quality as uniformity about the desired target. As a result of the successful application of this operational policy, 99.5 percent of the products shipped in 1987 met customers' fitness requirements. In comparing ECD to other chemical companies, 7 out of 10 customers rated us number "1."

Key elements of our operation policy include management leadership and involvement; teamwork; involvement of all employees in continual improvement; and training of all personnel in job functions, quality responsibilities, quality disciplines, and statistical methods.

Our quality management process is based on the premise that all employees are managers of their processes. Thus everyone is responsible for leadership and involvement in the operations and improvement of the processes under his or her control. Management is responsible for creating a vision for the future and an environment which facilitates this overall process. Management is also responsible for obtaining total involvement, for demonstrating leadership in carrying out its functions in a defect-free environment, in providing resources that will make continual improvement a way of life.

Management leadership and involvement starts with the general manager of the Eastman Chemicals Division and his management team providing a management role model that is being repeated throughout the organization at all levels including the technician and operator level.

Teamwork exists when members of the company work together to achieve common goals. There are two specific types of teams

used to carry out the management principles of continual improvement and defect prevention.

The first type of team is referred to as the management team. These teams generally consist of a supervisor and those reporting directly to the supervisor. These teams have the primary responsibilities for operating the processes and for achieving the improvements that evolve through process control and defect prevention. These teams are also responsible for meeting regularly to review the team's performance, identifying improvement opportunities within their management system, and establishing quality improvement teams.

The second type of team is a problem-solving or quality improvement team. These teams are formed for a specific purpose and consist of members making unique contributions. These teams may cross organizational boundaries and management levels and are dissolved when the purpose of the team is achieved.

The strength of an organization is a full utilization of the knowledge and skills of the people. Training is an essential strategy for improving knowledge and skills. Training and the search for knowledge are continual processes requiring internal and external training resources.

Our management process is designed to enhance the quality of worklife by providing each employee with their appropriate training, tools and environment to enable meaningful participation in the management of the Eastman Chemicals Division.

Eastman Chemicals Division recognized over several years ago the importance to both the local and national economy of encouraging and facilitating the spread of quality management techniques. An executive vice president of one of our largest units compared our treatment of safety information as a way in which the public good outweighs any short-term competitive disadvantage. This recognizes that in the long term ECD's best interest is served by strengthening the local and national economies generally, and our customers' and suppliers' operations specifically. Therefore, ECD has allocated resources to meet the needs of specific outside organizations. Members of management and quality facilitators/consultants have given quality presentations and quality training programs to customers and suppliers as a part of our customer/supplier partnership program.

With encouragement from ECD management, local presidents of 15 technical and professional societies combined to form the Appalachian Quality Council to promote the quality concepts in the local community. Through their efforts, a "Quality First" program has been under way for two years, with over 70 local enterprises having participated in the transformation of American industry training models. This program has resulted in documented savings in the millions of dollars in improvements for these organizations.

In addition, our company has assisted the Kingsport Area Chamber of Commerce in its quest to establish a National Center for Quality. The mission for the National Center of Quality is to create communities of excellence by achieving improvements in quality and productivity in government, business, industry, and service organizations.

The National Center for Quality will complement the "Quality First" program, which is project oriented, by providing the training for managers and executives in order to sustain the quality movement beyond the project phase.

The Center will be committed to providing training and consulting to communities regardless of their location. These centers offer the opportunity for the Federal Government to assist in supporting technology for training government and business leaders in the implementation of quality principles. The staffs of Congressmen Quillen[4] and Ritter are aware of the work being done, and are looking for ways in which the Federal Government can be supportive. In fact, the President of the Kingsport Chamber of Commerce and the mayor of the city will be here in Congressman Ritter's office tomorrow meeting with some local representatives from the city and businessmen in this area to talk further about sharing this information between these two cities.

The Chemicals Division is on a journey to improve the competitiveness on an international basis. As a result of our focus on quality improvement. the following performance factors have been realized since 1985: sales increased 11 percent, cost to the percent of sales down 12 percent, earnings from operations increased by 112 percent.

In achieving these results, we have also attained the following 1987 indicators of excellence: quality of products, 99.5 percent met customer fitness requirements; quality of our services, 97 percent of our products were shipped as promised; and customer satisfaction, 71 percent of the customers rate us number "1."

Within the Eastman Chemicals Division, we are using many quality management techniques that are unique to our industry. With quality as a way of life throughout our entire organization, we are using aggressive, innovative methods to continually improve quality of our products and services.

I believe there is an awakening that is taking place throughout the U.S. manufacturing and service organizations to the fact that if we are to compete successfully worldwide, we must improve the quality of our products and services. More and more companies are turning to the quality management concepts as a way of improving the quality of their products and services. As they begin applying the quality management concepts, more companies are recognizing the fact that better satisfying customer needs by improving the quality of their products and services will produce—will improve productivity and reduce costs. Therefore, quality management is becoming the strategy to compete successfully worldwide. As this transformation takes place, however, customers are demanding even higher levels of quality. Therefore, this is not a journey that has an end, but an ongoing process of continual improvement to better meet future needs of the customers worldwide.

Two key factors in our improvement strategy are to provide everyone within our organization with the knowledge to continually improve their operations and more importantly to provide the recognition and reinforcement for the application of this knowledge.

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[4] Hon. James H. Quillen of Tennessee.

Our Government has established a process to ensure continual improvement and the sharing of knowledge among all organizations within our country. This process is the Malcolm Baldrige National Quality Award. The Award provides recognition for organizations that have achieved preeminent quality leadership and provides a process for sharing knowledge among all U.S. organizations. With respect to other areas in which our Government can help improve the competitiveness of American industry, the chairman of the board and chief executive office of Eastman Kodak, Colby Chandler, made the following statement, and I quote: "In the last decade manufacturing has reordered our priorities, putting a premium on long-term results and quality. We are doing everything that we can to compete, and will be better able to do so when our government lets us compete. We are seeking neither protectionism nor a handout. We are seeking economic policies which promote economic growth, not just for manufacturing, but for the economy at large. We need an informed and thoughtful debate on these matters. We face very hard choices and difficult adjustments." Thank you.

[The prepared statement of Mr. Jackson follows:]

U.S. House of Representatives
Committee on Science, Space, and Technology
Presentation by Francis W. Jackson
Director, Quality Management Planning
Eastman Chemicals Division of Eastman Kodak Company

Eastman Chemicals Division, a division of Eastman Kodak Company, has a proud history of meeting customer needs with products and services that are high in quality and value. However, we recognize that quality that was good enough yesterday may not be good enough today. Likewise, products that meet today's quality standards will not meet tomorrow's requirements. Therefore, Eastman Chemicals Division (ECD) is taking aggressive measures to continually improve the quality of its products and services.

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ECD is achieving excellence and meeting tomorrow's challenges by effectively using quality management principles. Quality management is being used at all levels and in all functions of the organization as the system for managing our business. ECD is achieving its mission and vision through the broad application of a "quality control and improvement model." By doing this, we are attaining our quality goal -- to be the leader in product quality and value.

The Eastman Chemicals Division started the implementation of quality management concepts as a result of losing market share in a major product during the late 70's. The strategy that was used to regain the market share focused on improving quality of products as well as improving the quality of managing our processes. The result of this effort allowed us to regain our market share position but, more importantly, demonstrated that focusing on improving quality also yields improvements in productivity and reductions in manufacturing costs. Our successful experience in the application of quality management concepts resulted in a massive management-led project to implement quality management concepts in every aspect of managing the Eastman Chemicals Division.

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of ECD and his management team providing a management role model that is being repeated throughout the organization at all levels including at the technician and operator level.

Teamwork exists when members of the company work together to achieve common goals. There are two specific types of teams used to carry out the management principles of continual improvement and defect prevention.

The first type of team is referred to as the management team. These teams generally consist of a supervisor and those reporting directly to the supervisor. These teams have the primary responsibilities for operating the processes for achieving the improvements that evolve through process control and defect prevention. These teams are also responsible for meeting regularly to review the team's performance, identifying improvement opportunities within their management systems, and establishing quality improvement teams.

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In addition, our company has assisted the Kingsport Area Chamber of Commerce in its quest to establish a National Center for Quality. The mission of the NCQ is to create communities of excellence by achieving improvements in quality and productivity in government, business, industry, and service organizations.

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The Center will be committed to providing training and consulting to communities regardless of their location. This center offers an opportunity for federal government assistance in supporting the technology for training government and business leaders in the implementation of quality management principles. The staffs of Congressmen Quillen and Ritter are aware of the work being done and are looking for ways which the federal government can be supportive.

The Eastman Chemicals Division is on a journey to improve our competitiveness on an international basis. As a result of our focus on quality improvement, the following performance factors have been realized since 1985:

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Two key factors in our improvement strategy are to provide everyone within our organization the knowledge to continually improve their operations and to provide recognition and reinforcement for the application of this knowledge. Our government has established a process that encourages continual improvement and the sharing of knowledge among all organizations within our country. This process is the Malcolm Baldrige National Quality Award. The Award provides recognition for organizations that have achieved preeminent quality leadership and provides a process for sharing knowledge among all U.S. organizations. With respect to other areas in which our government can help improve the competitiveness of American industry, the Chairman of the Board and Chief Executive Officer of Eastman Kodak, Colby Chandler, made the following statement:

> "In the last decade manufacturing has reordered our priorities, putting a premium on long-term results and quality. We are doing everything we can to compete, and we will be better able to do so when our government lets us compete. We are seeking neither protectionism nor a handout. We are seeking economic policies which promote economic growth, not just for manufacturing, but for the economy at large. We need an informed and thoughtful debate on these matters. We face very hard choices and difficult adjustments."

Mr. ROE. Thank you, Mr. Jackson. Now, we have with us Mr. Elbern H. Alkire, Air Products and Chemicals, Inc., Mr. Alkire.

STATEMENT OF ELBERN H. ALKIRE, AIR PRODUCTS AND CHEMICALS, INC.

Mr. ALKIRE. Thank you, Mr. Chairman. You have before you my written testimony which I would like to have entered into the record.

Mr. ROE. No objection, and so ordered.

Mr. ALKIRE. What I will do is just briefly comment on a few of the points, and touch on a few concepts that have already been mentioned by my colleagues on the panel.

A recent issue of "American Demographics Magazine" in February, 1987, reported on the results of a poll conducted by the Roper organization in which they asked people from various countries what percent of those people said that "Made in America" was a mark of quality. And the results are as follows: Americans, 69 percent; Italians, 34 percent; French, 25 percent; British, 9 percent; West Germans, 6 percent.

So, the reputation that we once enjoyed for quality has certainly deteriorated as indicated by the poll. Fortunately, they did not ask the Japanese what they thought "Made in America" meant.

In my testimony—written testimony—there are a number of points about quality that I would like to reinforce. First of all, that is "quality" itself does not refer to high price or high purity or the goodness of a product, it is instead a measure of how well a product or service meets the needs and wants of its customers or users. So, therefore, it is something different than you might have thought when you think of a particular product that is—that has won the reputation of high quality.

Secondly, that this concept of quality applies to all functions of an organization, not just manufacturing and not just sales or engineering and marketing but all of the other functions that an organization conducts in order to operate as a business entity. This would include accounting functions, the billing process, all of the various transactions that a user or customer would have and come in contact with that company that creates this image of quality if you will.

So, therefore, the attitude of the person who answers the telephone and takes the original order is important in creating this atmosphere and this idea of whether or not dealing with your company is a quality experience. If you have ever purchased something in a department store, and then had the bill come to you and have the bill be incorrect, and then the frustration of having to go back and correct the bill, deal with their accounting people and everything, creates a feeling that maybe you are not too happy about the way that store handled the transaction. And whereas the product that you bought may be very good, if you do not like the way they handled all the other things that were part of that transaction, that has an impression on you with regard to quality.

Third, the individual who determines the quality of any product or service is the customer. The persons who use the product determine whether or not it meets their needs, it meets their expecta-

tions. So, in order to determine if you truly are achieving quality in the products and services that you provide, you have got to measure customer satisfaction.

And finally, as has already been mentioned, the achievement of quality all throughout an organization is an ongoing process and it is this process of continuing improvement. It starts by measuring customer satisfaction. Next, it identifies problems that occur in achieving that satisfaction 100 percent of the time. Then, putting in place corrective programs in order to fix those problems in a way that they cannot recur, in fact, improving the operation, improving what it is that you do. And then finally remeasuring the customer's satisfaction.

There is a PIMS data base, which is the Profit Improvement of Market Strategy data base that is compiled by the Strategic Planning Institute in Cambridge, MA. They gather independent data from business and industry all around the country. They have information from about 2,000 different business units. In analyzing that information and analyzing the strength of the companies involved, the strength of the business units, they find that one of the most significant factors in determining profitability, return on investment, and market share of any business is the relative perceived quality of its products and services by its customers.

I believe the challenges before us in any institution or any company really revolve around a few key points. First of all, we are going to have to change the systems within which we are operating, because the systems that we have now, some of the traditional systems of managing and operating, are not working as well in the global marketplace as they used to work domestically.

Secondly, we must create a whole new set of attitudes on the part of employees and management. We must empower the employees to take charge of their own activities and their own operations. And we must imbue in everyone this spirit of working toward continuous improvement of what it is that they do.

Air Products appreciates the opportunity to testify before this committee on a very vital issue. And we look forward to commenting further during the question and answer session. Thank you.

[The prepared statement of Mr. Alkire follows:]

TESTIMONY

OF

ELBERN H. (ED) ALKIRE

AIR PRODUCTS AND CHEMICALS, INC.

BEFORE THE

COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY

U. S. HOUSE OF REPRESENTATIVES

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BETHLEHEM, PENNSYLVANIA

QUALITY IMPROVEMENT AT AIR PRODUCTS

Overview

Air Products and Chemicals, Inc. is engaged in a comprehensive effort aimed at achieving quality--defined as consistent conformance to customer expectations--throughout its operations. Evidence of this quality process is everywhere--from the thousands of employees who wear quality pins, to a videotape in which the company's chairman, Dexter F. Baker, tells employees, "Let it never be said that Air Products is second to any company in the quality of its products and services." By late 1988--only three years after formal efforts began--all 12,000 employees will have received training in the quality process. All employees will be involved because the concept of customer satisfaction goes beyond the traditional interpretation and includes fellow employees who in one way or another depend on their colleagues for services.

The quality improvement process is not a corporate reaction to poor products or services, or to an inability to meet customer needs. On the contrary, Air Products is widely recognized for the quality of its management, operations, and employees. It has earned a reputation as the premier industrial gas company, in part because of its strong customer orientation and proven record of developing new applications for its products. In its other core business, chemicals, where Air Products enjoys leading business positions, the company has a reputation as a high quality supplier. During the past several years, Air Products has received major awards from satisfied customers, including Motorola, General Electric, Ciba-Geigy, General Motors, and AT&T. This spring Air Products earned a supplier award for excellence from Motorola for the second time.

The motivating force behind Air Products' quality improvement process is the recognition that customers' expectations are continually changing and that diligence in anticipating, understanding and responding quickly to these changes is essential to the company's drive for excellence and future success. Through the quality improvement process, Air Products expects that all employees will continually and consistently conform to their customers' everchanging expectations. The customer satisfaction which will follow will result in stronger market positions, improved profits, and increased opportunities for all employees.

Philosophy and Approach

The quality improvement process at Air Products is aimed at strengthening employees' attitudes and values toward performing their jobs to satisfy, consistently, the expectations of their internal or external customers. Since virtually all departments either are directly involved with external customers, or support others that are, ultimately the entire corporation will be uniformly focused on the external customer, satisfying their expectations -whether related to product quality or, for example, the accuracy and speed of invoicing procedures.

In theory, this process seems simple. In practice, it requires strong and directed management, and widespread employee education and support to achieve the desired results. Achieving total quality is the shared responsibility of each employee to find improved work methods and to identify situations which lead to dissatisfied customers and costly, after-the-fact quality control

attempts. These fundamentals must be accompanied by annual goal setting, results measurements, achievement and employee recognition programs, and ways to measure customer satisfaction on a continuing basis.

Implementation of the quality process requires a shift in corporate culture and values that places more emphasis on employee involvement, sensitivity to customers, teamwork and innovation. Management's job is to work on the systems that produce the results and to improve the systems continuously with the help of all employees.

Evolution and Implementation

The quality improvement process at Air Products had its roots in the productivity steering committee which the company formed in 1980. Under the direction of Dexter Baker, who was then president and chief operating officer of the company, the committee oversaw the identification and implementation of hundreds of productivity initiatives which have resulted in documented savings in excess of $80 million over the past six years.

Four years into this formal productivity effort, the committee concluded that new opportunities for technical productivity improvement (i.e. higher energy efficiency, improved production yields, lower capital and operating costs, etc.) were diminishing due to the program's cumulative successes. The committee then began considering other non-technical areas for improvement, such as employee attitudes and values. The search for more inclusive productivity approaches prompted the committee to invite Dr. Joseph Juran, a recognized expert on quality, to visit corporate headquarters. Air Products

also became familiar with Philip Crosby and his principles, and shortly thereafter, the company's chemicals group began sending its management to Crosby's Quality College in Winter Park, Florida. By the end of 1985, a systematic quality improvement process was being fully implemented in the chemicals group under the leadership of Frank Ryan, who was recently elected President and Chief Operating Officer.

During 1986, the company's other operating and corporate staff groups undertook a similar quality improvement process, tailored largely on the 3M methodology. Al Greene, who had previously served as Air Products' corporate safety director and as a manufacturing manager in the chemicals group, was appointed to the newly created position of corporate director of quality systems, reporting directly to Mr. Baker. Also, quality managers were appointed for the company's gas and process systems groups. Responsibility for the company's overall quality improvement process has been assumed by Air Products' 14-member management committee. Progress reports on quality have assumed a permanent place on this group's agenda.

Companywide educational programs are nearly complete. Every senior officer and all line and staff vice presidents have received several days of formal quality training. By the end of 1988, all 12,000 employees will have received basic quality training through the efforts of Air Products' sixty quality instructors. On September 9, 1988, Air Products will celebrate Quality Day at Trexlertown headquarters, to recognize the end of this phase of training. Key ingredients for quality improvement--management commitment and leadership, organization, and education--are well in place.

Results and Accomplishments

Results of practicing the quality process will be seen over many years and are expected to be far reaching in every area of activity. Ultimately the results should provide Air Products with a competitive advantage in our markets.

The achievement of quality is an on-going process of continuous improvement. It follows the cycle of measuring customer satisfaction, identifying problems or shortcomings in achieving satisfaction, solving the problems in a way that prevents them from recurring, and then remeasuring satisfaction. Surveys of external and internal customers are being conducted to identify areas of opportunity for improvement. In addition quality climate surveys have been conducted of employees throughout the company to determine what internal opportunities need to be addressed. Ideas generated during the quality workshops also provided thousands of additional suggestions for internal and external customer satisfaction improvements.

The results of those surveys and workshop ideas have led to the formation of hundreds of teams of people throughout the company working on corrective actions and quality improvement. These teams draw upon the talents and expertise of employees at all levels in the organization and have had a significant impact on both external and internal customer satisfaction. Representative examples of their efforts are being featured in "Success Story" reports to the corporate management committee each month. Recent stories featured a steel manufacturer who not only reduced monthly costs by a documented $100,000, but also significantly increased their oxygen purchases from Air Products. This is an example of what happens when our plant

management aggressively seeks to meet external customer expectations. Internal departments like Chemical Group Customer Service have been able to significantly reduce costs and delays in the billing cycle by developing a keener understanding of internal customer requirements.

Plans for the Future

As the quality process gains momentum at Air Products, the need for additional skills training has become apparent. Evaluation is underway of workshops in the problem-solving process, participating in a problem-solving group, leading a problem-solving group, and applying problem-solving techniques. This advanced quality training will make the process of continuous improvement more effective and will further develop the capability of all employees.

With the efforts in quality improvement well established within the company, the corporate purchasing organization in early 1988 published a guideline for suppliers. This guideline introduced our suppliers to the Air Products quality process and introduced the requirements and expectations they will need to meet as a quality supplier. Air Products has worked for years with its suppliers from the chemical industry which has come a long way in sharing statistical quality control (SQC) data to improve product consistency and develop partnerships in product supply. Examples of companies who have taken the lead in this are Celanese, Eastman Chemical and Exxon Chemical. We are looking for extended relationships with all key suppliers, so that we can work as partners and derive mutual benefits.

Concluding Remarks

During the decade of the 1980's a widespread movement has developed across the U.S. to improve the quality of our country's products and services and thus become more competitive in the global marketplace. Led by companies like IBM, 3M and Ford, American industry is moving toward acceptance of the concepts of quality, continuous improvement, employee involvement, management of processes and systems, customer satisfaction, and problems as opportunities for improvement. These concepts represent a major change from the centralized management techniques and system used for so many years earlier in this century. While most major U.S. corporations have recognized the importance of quality as a competitive necessity and are in various stages of implementing quality programs, we as a nation have only begun. Translating the promise of quality into real competitive advantage and regaining our country's international competitiveness will require all to go beyond incremental changes and transform the way we do business.

Government has a vested interest in the success of these efforts. Sustained improvement and ultimate reversal of the trade deficit will only be achievable when the products and services the U.S. offers are better than those available elsewhere in the world. There are a number of actions the government can and should take. By supporting and managing the Malcolm Baldrige National Quality Award, the government recognizes quality achievement and excellence of U.S. companies and promotes awareness of the close connection between quality and domestic or international market success. The challenge to government is to

stay abreast of nationwide developments in quality (for example, through hearings such as this one), to encourage the practice of the quality process and continuous improvement throughout the country, and to apply these practices to government operations and activities at the federal, state and local level.

E. H. Alkire
22 June 1988

Mr. ROE. OK, now we can get into it. The Chair recognizes Mr. Ritter.

Mr. RITTER. I want to thank our witnesses for some excellent testimony. And I will start with them chronologically back to Roger Nagel, and I have my notes scattered about here, because I thought the chairman was going to go first on questions.

Dr. Nagel, you talked about getting back a much—a much more elevated priority, I guess, for manufacturing in America. Are you saying that we have relegated manufacturing over the last several decades to something less than a high priority, that between our government and our academic institutions we have, until recently, been less than attentive to the needs and necessities for a modern, technological society based on manufacturing?

Dr. NAGEL. Yes, I think it goes even further than that. I think we have kind of taken manufacturing for granted. We have scripted our children starting with grade school that manufacturing is not necessarily an occupation where you will do well or feel a sense of success like you would maybe in other occupations. And until recently, there was a notion that academics who either studied or taught manufacturing were those who could not succeed in the other technical engineering disciplines. It is only with the revitalization that has come from the changes in new technologies has the interest changed, and that has been slower than as required.

Mr. RITTER. Is part of the responsibility, the responsibility of the federal government, that perhaps the federal government in itself in its creation of a new R&D economy did not really encompass manufacturing in that R&D economy? Institutions like Lehigh or MIT or Stanford or whatever went in a different direction based more on science than on practice?

Dr. NAGEL. I think the Government has also taken manufacturing for granted. Perhaps because there is not a single advocate by mandate or by law. One agency of the government is supposed to watch for it. Perhaps because they too felt that it would be taken care of by just putting money into science and technology.

But, for example, about a year or two ago, the government funded the so-called Department of Defense University Research Initiatives. A large number of research initiatives identified by agencies of DOD for importance, very few of which mention manufacturing and even fewer which funded manufacturing. Yet the Defense Department is now contemplating creation of a manufacturing science force, just because they think that it is a very critical factor in the success of the Defense Department. So I think there has only been a more recent awakening to the potential impact of the importance.

Mr. RITTER. Yes, you mentioned the growth of the new and available technologies. I would also add that the global competitive challenge and the kind of fierce, ferocious competition that American companies and our industries are faced with, I think, really pushed us to reconsider the importance of manufacturing.

You mentioned an agenda for manufacturing. You mentioned some cohesion at the Federal level. I think you would find agreement from the chairman and myself and others, but where does it exist in the federal government, this potential focus? Everybody has—each agency has its own mission. Defense has a mission to

produce weapons. The Department of Transportation has got a highway, an airport mission. EPA has got an environment mission. We do not have right now a focus that cuts across and is oriented also toward the private sector needs and demands for this baseline, from the engineering students on, to the cohesion that is necessary to have the best systems.

Dr. NAGEL. Well, I think that is in fact the problem that I perceive and one that has been perceived by a number of National Academy committees. Potential places for a focus would, in fact, be the Department of Defense maybe through the Manufacturing Science Board. In the civilian sector maybe it would be at the National Bureau of Standards as a place where the advocacy could be held. The National Science Foundation would be another such place, DARPA would be yet another. And all of these agencies are beginning to take a much harder look at manufacturing as it begins to impact our own mission.

Mr. ROE. Gentlemen, I want to see if we cannot have a little bit of a freer exchange of views rather than go back and forth.

Dr. NAGEL. I would be more than happy to——

Mr. ROE. No, no, no. You are making a point, and you are coming at that, your observation, from the academic world. Fair play? You are making an assumption; I do not mean this critically. There is an assumption made—yes, I know of your background and your enormous contribution to industry. There are assumptions made that because we refer, and I know this Doctor who is going to testify here today and you know, we refer to the National Bureau of Standards, we refer to this DARPA group, we refer to Defense, and we refer to this—assuming that all of those people and agencies and meaning no effrontery to them whatever, are all on the same wavelength. Therefore, we make an assumption that if government does its thing, how does government do it? And if you were to put that under one agency and one set of circumstances, put it under another—because each one has their own agenda. And I do not say that disrespectfully.

One of the major problems that we are faced with in Congress, is that you've got the committee system and all kinds of legislation emerges, you know, somebody talks about how we are going to solve the drug problem, and the press is filled with what a great achievement they made in this particular agency or that particular section of the bill. There may be 50 issues related to the drug problem, and none of them coordinate or work as a single direction.

I am leading to a point, because there is nobody that has been nailed down to do that as their particular function. This also includes the Cabinet levels. In other words, the fact that you have the Department of Commerce, one would think that everything would go to the Department of Commerce. Half of it would come out of Defense, half would come out of other agencies and whatever.

What I am trying to get at is, I hope that when we conclude at least our observations today, that we will recognize that there is not any sacrosanct section here that has been established that would achieve these goals. Do you understand what I am trying to say? Should it be a whole new coordinator?

Dr. NAGEL. Well, I agree with you that there has not been one. In committees that I have served on and others have, there have been suggestions that there should. I would find it presumptuous of me to say who it should be. I mean—it could either be an existing one or a new one. Sam has a report that the National Academy just put out that again calls for one, and that maybe he should make reference to it.

Mr. ROE. Go ahead, Sam.

Mr. KRAMER. If I may, the Academy has taken up that one question just recently, and in fact the report was released in April 25 on the "Technological Dimensions of International Competitiveness," and it addresses this question that you raised, Mr. Chairman. And they come out with a series of recommendations; there is no answer, but it is the government's responsibility or it is industry by itself. And in fact, they lay out an agenda in here down to state and local governments that have a responsibility as well as the private sector to address the problem. But in that one question, if I can quote from their summary statement, I was showing it to Roger here. Under—they break it under, "Federal Government, Academic, State and Local Government." But under the "Federal Government," they say, "To facilitate the improved cooperation between government and industry, the committee recommended that a single government agency or council be designated to respond to industry initiatives and serve as a liaison to industry and other private groups."

I think what they are saying, and it is presumptuous of me, not having sat in the hearings, but John Lyons was a member of this committee. Right now, if Roger from academia wants to approach the federal government, he has to go out and approach a multitude of agencies. And as you say, everyone has their own agenda. Likewise, industry interacts with government, has to go to many different places. And I think what they are saying here is there should be at least, while not one place in managing it, some place there could be a coordinator of it.

Mr. RITTER. I would just disagree on that point. Our committee this past year has developed new legislation changing the National Bureau of Standards to a "National Institute for Technology and Standards" and has tried to address some of this problem and in a sense we have chosen NBS, being the Federal agency with a kind of broad scope to be enhanced and expanded to kind of take into account the cross-sectional needs of America's private sector competing with foreign nations incorporated.

And maybe—and that is by the way in the trade bill, and that encompasses with the Hollings approach from the Senate side. And I think we will have a chance with the trade bill process to begin formulating some responses.

I would just like to ask a couple of quality questions. As you hear Mr. Jackson and Mr. Alkire talk, you get the impression that there is something that is really important that is beginning to cut across the length and breath of American industry. But when you look at this issue and say the business schools which train managers, it is not really in the business schools. It is out there tremendously in the private sector and especially in those companies which are making lots of money and are growing; but you barely

see it in our nation's leading business schools. Where, how do we get this pool of young people who are going to be steeped in knowledge of technology, knowledge of management, knowledge of psychology, knowledge of some of these principles? Is it all a private sector initiative or can there be some merging? What should we in the Government be doing? Should we be sponsoring work in this area? Should we stay out of it? Should we be applying it in our own agencies as you see little bits and pieces, little bridgeheads of quality, total quality management coming through OMB of all places? What, how does this thing expand more effectively into the American scene?

Mr. JACKSON. A couple of comments I would like to make in response to of that. I think I had mentioned the fact that the universities—now the departments are cooperating to try to better meet the needs of industry. And I think that is where the——

Mr. RITTER. Speak up, because I do not think the——

Mr. JACKSON. OK, I think Dr. Nagel mentioned that you see more cooperation between the departments within the universities and colleges in the country trying to address the needs of the industry today. And I think you will find some examples where the engineering departments and business schools are cooperating to try to meet the needs of the future. They are a little bit late, at least they are making progress——

Mr. ROE. They are late and a lot of them are tenured up.

Mr. JACKSON. That is correct.

Mr. ROE. A lot of the newer minds and ideas find tough sledding getting in. How does industry accelerate that? Can they?

Mr. JACKSON. Well, I think industry has to have influence on the universities, and be sure that they understand the needs they have for the future. Like they were talking about the technical needs, there is also a need for people to have the understanding of this quality movement. And I think the University of Tennessee in Knoxville is one of the leading schools where the business school and engineering school have jointly developed programs that have been in existence for about 5 years.

I think a second way is to help support some of these communities' efforts like has taken place here in Bethlehem, to try to develop locally programs to train people who are already in business, to how to apply these concepts at a local level. I think these grassroots on quality management progress could spread throughout the country. And I think the federal government could help support this in some way with some initial seed money.

Mr. RITTER. You know, you mentioned the coming together of Kingsport and Bethlehem tomorrow, I think in Washington. The mayor of Kingsport is going to meet with the mayor of Bethlehem and try to talk about how Kingsport has achieved bringing quality principles into the management of city government and been very successful with it.

Mr. JACKSON. That brings up a third point you mentioned, and I think you all have a role to encourage government to apply the same concepts to the government process. Because if there is waste in industry, certainly there is waste in the government process. And these same concepts can apply there. And if applied successfully, they could have dramatic improvements.

Mr. RITTER. There was a federal conference on quality about 3 or 4 weeks ago. And about 1,400 people attended. And they are talking about the potential savings of tens of billions of dollars by simply engaging the quality management principles, translating them to the federal workers and also bringing the federal worker up to a level of contribution where he or she has not normally been. Ed, do you have any comments?

Mr. JACKSON. Just one comment before we go on. I think there is an opportunity to recognize the improvement within the federal government. Only through recognition and reinforcement will that continue.

Mr. ROE. It is interesting to me—I was listening intently. For example, we look like we heard each other. We came back and, Mr. Alkire says, that "made in America, customer satisfaction, changing the system and the management is not working," but each—and I do not mean this skeptically—each one of what you are suggesting is part—as you see the issue, is what of course is the purpose we are here. But let's talk—what is quality management principles? And I do not mean to be facetious. What—I dare say if we were to ask each one of you, what you would determine quality management principles to be, I think we would get a different response from each person.

So, I am just wondering if the—if we are comparing ourselves to the work ethic of the Japanese, who have a total involvement from a national level, a total involvement in everything they do is their interpretation of quality management principles. It is part of their culture.

If you try to apply those same Japanese principles to the United States, they would throw us all out because we would be taking away from them their individualism, so to speak. Who wants to respond?

Mr. ALKIRE. Mr. Chairman, I would like to clarify one thing. You refer to the Japanese management principles or styles or what have you; I would suggest that if you look back in history, those are American principles that were taken to Japan at the end of World War II by gentlemen like W. Edwards Deming, the quality guru who went over there at the request of the occupation forces, and Dr. Joseph Juran. And a number of things that they taught about project management, about statistical quality control, about the various principles that they should embody in their way of managing and their way of operating, including promoting from within, are all things that they learned from us. And they have just learned how to practice them so well, and they have come back to us and are using them as a very effective means of producing products that are superior.

Mr. ROE. We talk of what role should government play, and we get into the debate of that, the business community says, "By God, keep government out of it." I hear that every place I go. That does not matter whether it is a red light or a green light, or the road is painted blue, somebody is going to complain about it. Then we get to the point that business comes back, and business says to government, "hey guys, you know, stay out of it. We do not want to get involved with the government, vis-a-vis the point of view of the anti-trust situation." Academia comes back and they say "well, we

are big science versus small." And we talked about that, big science versus small science, our schools would go to small science, we don't want to get into it, and so forth.

Interesting point, however—or case in point, when we wrote the Clean Water bill in 1972, there were 17 different committees or subcommittees in the House and the Senate that had an element of jurisdiction. It would have been impossible to write that bill today under the structure, the institutional structure today. At the time, in 1972, you did not have those same rules where a Speaker simply says, he assigned that bill to Public Works, and Public Works went out and wrote the bill and in 6 months time that bill was produced. So, that when government played the role in that direction, it had delegated a particular agency, if you like, within the government to achieve that goal. I think that is the point that we were both making here earlier.

So, that when I talk about DARPA, and I am not running down DARPA because DARPA is going to be testifying, DARPA has a particular challenge, if you like, a responsibility has been assigned to them from the Congress who says, hey, we want to look at technology transfer here, we do not want to be transferring anything, and you guys have to keep an eye on this, it is going to put us in a secondary position as far as the Soviets are concerned or whomever. And they carry out that particular function.

Where I am coming from is, do we think we arrived at a point where we should specify by legislation at least the framework of what quality management principles would be as we see it, and assign it to some central agency, either the Bureau of Standards as we talked about, or have somebody coordinate for the Federal Government? I happen to believe that in the 21st century that we have absolutely got to coordinate the productivity and capability of business, academia and the government working in one direction. We cannot say that—let's see, we cannot really say that to industry, "well, hey guys, we want to do this, that, thus," *et cetera*. Then we take away the capital gains issue, we take away investment credits. To me that is a stupid policy. It does not make any sense. You know, you might come back and say, "well, we are not going to start to teach science, space, and technology until you get to sixth grade." You are too old when you get to sixth grade, the kids are all in a different direction. Why don't we teach it in the first grade?

So, I think that there is a series of basic fundamental positions that have to be made as a national policy and then move on from there. At least that is my view. I do not know how you may feel about that. Dr. Nagel, do you have anything?

Mr. JACKSON. You mentioned establishing some kind of a national definition. In essence you have done that with the Malcolm Baldrige National Quality Award.

Mr. RITTER. I might add, that the bill establishes the National Institutes of Technology and Standards, out of the National Bureau of Standards, and contains the kind of best practices or at least information base located at the National Bureau of Standards or the NIST.

You mentioned that—the Chairman asked whether or not we could do it so to speak, could we catch up? You mentioned that,

well, it was invented here. And is there any doubt in any of your minds that the American worker is able to apply quality principles and be the very, very best in the world? Is there any question that we have?

Mr. ALKIRE. No, I do not think there is any doubt at all. I think the thing you must remember is that when we get into the kinds of problems that exist, the kind of things that stand between us and achieving what we want to achieve—that, I think it was Edwards Deming that said that 85 percent of all of those problems are the result of the systems that are in place and not the workers

Mr. RITTER. He blames management.

Mr. ALKIRE. Yes.

Mr. JACKSON. I think Toyota—which has a plant in Tennessee, I believe—the productivity and the quality of American workers there is superior to their counterpart in Japan. So, that is proof of the fact that it can be done.

Mr. ROE. Roger.

Dr. NAGEL. I want to respond to the Chairman's question about should you mandate something. I firmly believe we need a focus, and we need to make information available to facilitate cooperation, collaboration and all of those things. I do not think the federal government will make a positive impact by saying, here is how you get quality, follow this check list. I think they might well provide a focus discussion and list for seeing, but I do not think, you know, follow and this should become the law. Because I think all of these things are constantly evolving, and those cannot constantly evolve at that rate.

So, I see a role for providing for basically guidance, collaboration, and discussion and enhancement but not a mandatory sort of rigid set of regulations about and here is how we will achieve quality.

Mr. ROE. Maybe I was not making myself clear, what would—how would we still go when we ought to have states involved and we are getting involved. We are going to have local people get involved and so forth, but local groups are not, unless they are coordinating with industry that are working this area in a particular region, I do not know where they are going to get expertise or where do they get that expertise from?

Dr. NAGEL. Congressman Ritter has referred a couple of times to the bill establishing the National Technical Institute out of the NBS. There were a number of provisions there that I was very excited about and was hoping were going to come into place. In terms of providing for the information coordination and the grouping and even perhaps matching type funds, I think those kind of mechanisms, whether that is resurrected and passed or some other equivalent system is used, I think would be the right way to do that.

Mr. RITTER. Now, Mr. Jackson or Alkire, correct me if I am wrong, but from my contacts with American CEO's, chairmen and Japanese CEO's, chairmen and managers were ready for this quality issue. There is some indication that if the American workers are able to master the teamwork aspect of this—American managers really, and that we put the pieces together and work cooperatively as a team, there are some indications that the overall work product is superior. And this is coming from Japanese as well, to what can be achieved in Japan, because there is that individualism

on top of—the kind of the individual creativity on top of the group dynamic that can actually catapult the American worker and the American company ahead of the Japanese. Are there any thoughts you guys have on that?

Mr. KRAMER. Mr. Ritter, let me add one comment on quality, we tend a lot of times when we talk about quality to quickly revert our thoughts to labor and the labor force and the labor's commitment or ability to manufacture a product in a quality way. And that is not the whole quality issue. And I think we have to make everyone aware of it. We have been looking at this very closely and we had started to talk about defining quality as to a component of manufacturability and maintainability.

In fact, if I can quote John Lyons, in his recent assessment he says, "To assess quality one must ask whether the product as designed is reliable, serviceable and easy to manufacture and whether it does what it is supposed to do."

This has been—we just had a major seminar on that at the Bureau with industry and academia and everyone looking at the tolerances that you build into the design of a part so that it functions. Are you considering the capability of the ability to manufacture it? And that comes into the cost factor. And you can design something that can defeat the best labor force around, or you can look at a labor force and the machinery you have available and the intended use, can combine these factors together to give a very quality product. I think it is a much more complex, and there is many more people involved in determining quality than just passing it down to the guy at the bench making the part. I would defer to the people from industry since this is a government perspective on it.

Mr. ALKIRE. This is the point we talked about before. Every single person who works produces a product or service. That product or service goes to someone who needs it, who is a customer. The engineering people who design the product, their customer is manufacturing who has to take the design and then turn it into the final product.

So the sensitivity that has to be increased is for every person to think in terms of their customer and what the wants and needs of the customer really is. And in the case, for example, you mentioned the education system, the product of an education system is a graduate. The customer for the graduate is the employer in industry, the graduate school, and all the other folks to where those graduates go. So the customer—so industry or the educational system needs to get closer to the people who ultimately use those graduates, you know, to determine whether or not they are meeting the needs of their customer. Higher education is beginning to do this in the area of outcomes assessment, where they are in fact determining whether the result of their effort is in fact producing the desired outcome. We just need to link up the outcomes assessment with the needs and expectations of the customers of those graduates.

Dr. NAGEL. I have a question in answer to one of your questions, yes, whether we will have an advantage. Summed up simply put, we are moving from an era where people were told, that is the job and do it and do not ask any questions and do not make any vari-

ations, to here is the job and we want your best input, advice about how to do it right. And we want you to take pride in what you have accomplished. We are involving the entire work force if you will.

Mr. RITTER. Is this revolutionary or is this evolutionary?

Dr. NAGEL. I believe it is evolutionary. It is happening here now.

Mr. RITTER. I mean its impact on competitiveness, on our standard of living, on our jobs, on our work life? Is it revolutionary, this quality movement? Is it, or have we ridden the crest of the wave of the machines, and now we are seeking to gain the best from people? We placed a lot of stock in machines, but all of a sudden we realized that, hey, we have this plant with 5,200 people in it, and we pay 200 people to think—we paid them real well to think and to tell the other 5,000 what to do. But all of a sudden now we are saying, all of them—is that revolutionary?

Mr. JACKSON. I think it is both. You have got to have the workers doing just what he said to make a product as it is designed and made today to meet today's needs. But to meet tomorrow's needs, it may take new technologies they are talking about here, changing the whole process. Just like the gentleman from Bethlehem said that we changed the whole process in making steel in the last 2 or 3 years. So that takes technologies.

Mr. ROE. What we are basically talking about is—I think it is a misnomer to say quality—there are countless automobiles out there that are good quality, which ones do I want, which ones can I afford to buy. I do not buy—I buy a car within my area that I am trying to buy. Whether it is manufactured in the United States or Japan, it is the one that I buy. That is your customer aspect of it. So it is really a systems approach you are taking to the whole thing rather than the idea that there is one particular issue. Because I can remember before you were born in World War II when the Japanese said, made in USE or USA which was the name they just made up. And everything they put out came out like in crackerjack boxes and so forth and so on.

So in fact, and you mentioned the point that OK, you know, we sent Deming and others over there in the resurrection after World War II to help to teach them. They are doing a better job than we are, but that does not mean that we are not capable of doing the job.

Mr JACKSON. That is true.

Mr ROE. Now, is that part—I do not think it is just the idea of the smokestack situation at all. I think it went right across the board. Now, the question is that they are making good products as fast as we are, and are we going to be able to make good products and keep up with them or go ahead of them? That also does not just have to do with corporate decisions, if corporations should make the decisions unilaterally or academic decisions, it has to do with a national decision. Because some of the determinations that are being made by Congress are four in which we are trying to deal with quality production. We talked about that this morning. I mean, do we go ahead and do work with superconductivity? Do we provide the resources to do that? The Japanese are already talking about how to, one, how to produce the best material superconduc-

tively, they are already talking about how they are going to market the product.

And we are cutting back at Federal level. We are cutting back on the research moneys, moneys that are going into a whole host of fields of superconductivity. When we start talking about competitiveness, we start talking about the future of this country and our productivity.

Should we not be saying that proportionate shares of Gross National Products have got to be devoted to these particular areas? We've got to change the way we teach the youngsters in school. If we want to teach them science, space and technology, we've got to start in the first grade. That is not complicated. Why is it so complicated? I mentioned this morning, you know, the kids with these scientific toys they can play, they can make them up at 3 years old better than the parents can. So the capability apparently is there. Why don't we do it? Why should that take three generations to decide? Because there are about 30 different ways that we spend educational money. The media suggests anything about spending educational money, you get them down on your back. Then we do the space program—I mean the whole battle—I fought on the floor the other day to save the space station, they want to cut $400 million out of it—more housing, we need more housing, to take provisions and help the elderly. We need to help the elderly. We need to help the homeless.

The point we made, and we won the point, is based on the fact that if we do not go ahead and pull our best interests together and collaborate on what we are doing, then we are not going to be able to create the new wealth that is going to be needed to provide the resources that we need sociologically for the needs of people.

So, somehow I do not think it is—and the point you are making, I do not think it is an area that we can be a fiat from government, where government says you should do it my way. That is the last thing to say to our people, because if anybody said that to me, I wouldn't do it either.

But I do think that the psyche is beginning to develop, the attitude throughout the country where people are kind of proud if they can do something.

Dr. NAGEL. I think that is true. I guess I would like to add that knowledge is becoming a resource that is very important in competitiveness. I think we have an advantage in the infrastructure for providing education here if we use it well. And that is a comment I wanted to make back to you there.

Mr. ROE. If we apply it.

Mr. JACKSON. I acknowledge that and the environment where people want to do what you say are two resources we need to really nurture.

Mr. ROE. I think the federal government, for example, as we unfold what the space—what the space policy is going to be for this nation is going to trigger a whole forum on different technologies. They are going to be essential, and when we get to Mars, unless we have certain advanced technologies, these will be the points I am thinking of; fuel, materials, research, so forth and so on. We will never get there unless we do that. So I think as you make national

policies, in particular areas, it also is going to drive our economic base as I would see it and the competitiveness of the issue.

Mr. ALKIRE. But your national policy is——

Mr. ROE. Speak up, I can hardly hear you.

Mr. ALKIRE. Your national policies must come from national goals. One thing that was missing in all of our commentary was any mention of the fact that we had national goals, which we do not.

Mr. ROE. Well, I do not agree with that. Some people do not have a goal. I have a national policy goal for space in this country. We can make it work. We intend to see that we stay in space. So, I think we are coming down on the same side.

Mr. ALKIRE. Yes.

Mr. ROE. We are talking inspirationally. You know when John Kennedy made his speech about going to the moon, we did it in 9 years, unless it was 8 years, wasn't it, and so forth and so on. So, that there is—I think as we can stimulate the productivity, improvement of—we are talking about manufacturing, if we strengthen our goals is what you are saying.

Mr. ALKIRE. Yes.

Mr. ROE. I agree with you.

Mr. RITTER. I think his point is really well taken, because you know it is important that if you set a goal, you stick to it and you accomplish it and you go do it. That is what happen with the moon program. But if we can all remember, that as soon as we did that, we dropped it. Then we had a thing called Skylab, and we did it, and we dropped it. As a matter of fact, let the thing fall out of orbit. It is still a better space station then the so-called Mir, the Soviet space station. So the idea of setting goals and then having pretty much the majority go along with that over time, preserving is very important. I think this manufacturing area, and its connection with quality, it is kind of the machine and man and person together, needs to be a national goal not just a small piece of the action, because it really does—it really does serve as the linchpin for the creation of national wealth; manufacturing matters. The best service jobs are connected with manufacturing. You cannot send all that manufacturing overseas and expect to have the services.

So a national goal of manufacturing and quality is something I think we do not quite have yet, and that is what these hearings are about, to try to generate some of that consensus.

Mr. ROE. Two good questions. One is if anyone is looking for the federal government to lead the way in changing manufacturing technology? The government does not work that way or that fast. Business has to answer the question, how do we sell long-term quality awareness to a business community that traditionally has focused on quarterly short-term profits? That is a ringer. Go ahead, who wants to try it?

Dr. NAGEL. I will take the first one. I do not think we want the government to make the difference. I think we want the government to coordinate and provide a central focus.

Mr. ROE. OK.

Dr. NAGEL. And I think the answer to the second one is going to be the impact it has on the long-term health and meeting short

quarterly results is beginning to be less and less the right thing to do as you find out that the company does not stay competitive long. I think the marketplace is helping to bring that impact around.

Mr. ALKIRE. Air Products is devoting a considerable amount of manpower and funds, expenses to the education of all 12,000 of its people. And further to get them working on this process of continuous improvement without really seeing immediate short-term benefits. But the commitment is there. And as long as management will make that commitment and wait for the benefits to accrue and come 2, 3, 5 years down the road, that is what needs to be done. And the companies that are in a leadership role in this country; companies like Eastman Kodak, 3M, IBM, and Milliken and others, are doing that. They are making an investment now at the expense of short-term earnings with the knowledge that it is going to pay dividends in the future.

Mr. RITTER. By the way, Quality Valley, U.S.A. has its next program to bring in somebody from Hewlett Packard who has started—who has developed a system to try to connect this kind of spiritual, educational side of this quality movement to balance sheets and has developed a system what he calls "cost riders" to get other countries and the bureaucrats in the company realizing, a ha, this stuff really does make a difference. And so, you are all invited to that session. I think it is after the July 4th weekend.

Mr. ROE. Another question, Dr. Seymour Melman of Columbia University has argued that the Department of Defense penchant for maximizing performance heedless of costs has damaged the U.S. manufacturing center or sector. Does that make any sense?

Mr. JACKSON. No, it does not. I do not—I am not sure I understood the question.

Mr. ROE. They are coming back and saying that basically they are arguing that the Department of Defense's penchant for maximizing performance heedless of costs has damaged the U.S. manufacturing sector. I think what they are saying there basically is that when we look at the military procurement the money does not matter if you question the end result that they are trying to achieve. Now, how does that relate to other manufacturing centers?

Mr. JACKSON. I guess my response would be if the Defense Department would look at the quality of what they are getting, not the lowest costs——

Mr. RITTER. It is hard to hear you.

Mr. JACKSON. If they would look at the quality of what they are getting from industry rather than the lowest price, you will find out in a long run that in fact will be more cost-effective for them. So that would be my response. If I understood the question correctly.

Dr. NAGEL. His implication that it is damaging manufacturing, I would have to hear more of his argument. There has been a suggestion which was just made, that it would be wise for DOD to look at the life cycle performance instead of the performance of the one time it might work in its life cycle. And that would probably be the healthiest thing to do.

Mr. ROE. That is a paramount issue right now. OK.

Dr. NAGEL. A comment you mentioned earlier, which I think you mentioned about some of the changes in the tax law that have discouraged industry from investing in research. That is something that we really need to look at because that in essence would encourage industry to do more of what they have done historically and need to do to maintain a competitive edge of being able to first make a profit, and then take some of that profit and put it back into technical investments.

Mr. ROE. Well, it is my personal opinion that when that tax bill was written—first of all, part of it is a bomb, people are just beginning to understand it now. In my judgment both from the point of view of the manufacturer, there was a number of points there that were important to the country, that the country was benefiting from in the levels and percentiles of resurgence, and also the new entrepreneurs, where they could take advantage of capital gains and so forth which now of course is being wiped out. Where the citizen was involved, all of us as individual tax payers, the assumption that there would be one level tax rate—there are three different level tax rates, and the highest is what 28 percent, I believe, and therefore, everybody would be much better off, is just sheer nonsense when you look at it in retrospect, particularly when they had to devise the IRA program, where people could set aside part of their funding, which was an enormous success in this country in a matter of a year and half's time. It was the biggest saving device ever devised in the history of this country. And that was wiped out completely. So I think that when we talk about productivity, also we've got to talk about other government policies that is work productivity. You know what I am trying to say?

Mr. JACKSON. Yes, I agree with you.

Mr. ROE. OK.

Mr. RITTER. Well, of course, we will have to comment on that one just a little bit, because we lost the IRA over the battle for state and local tax deductibility. It was one or the other.

Mr. ROE. It should not have been.

Mr. RITTER. It should not have been. There was a more powerful political constituency for state and local tax deductibility, especially on the Ways and Means Committee.

Dr. NAGEL. I neglected to ask a motion that my advance testimony be made a part of the record.

Mr. ROE. No objection. No objection to it. All the testimony, the formal testimony is made part of the record. Thank you. Do you have any further questions?

Mr. RITTER. None for these gentlemen.

Mr. ROE. Any further thoughts that you would like to make?

[No response.]

Mr. ROE. OK, we want to thank you very much for your testimony. It has been a big help to us, and we will be back in touch with you further, I am sure.

Now, our second panel for today—that is panel No. 2, and it is the panel on superconductivity. And we have with us as our witnesses today, Dr. Kay Rhyne, program manager for ceramics and superconductivity, Defense Advanced Research Projects, Department of Defense, and Dr. Michael Notis, director of Ceramics Re-

search Laboratory and professor of Materials Science and Engineering, Lehigh University.

Dr. Rhyne has no written statement, so make your presentation be heard.

Dr. RHYNE. Yes, I will give you one later.

Mr. ROE. OK.

Dr. RHYNE. I apologize for not giving you one now.

STATEMENT OF DR. KAY RHYNE, PROGRAM MANAGER FOR CERAMICS AND SUPERCONDUCTIVITY, DEFENSE ADVANCED RESEARCH PROJECTS AGENCY, DEPARTMENT OF DEFENSE

Dr. RHYNE. Good afternoon. I appreciate the opportunity to appear before you and to discuss DARPA's program in high-temperature superconductivity [HTSC]. And again, I apologize for not having any written testimony available.

Mr. ROE. Why don't you pull that mike further, I know it is tough. There is a little one on your right hand side of that fellow there. We need both of them, actually.

Dr. RHYNE. OK. Is this OK?

Mr. ROE. I think so. We will try.

Dr. RHYNE. OK. In the recent "National Academy of Sciences Report on High-Temperature Superconductors," the panel concluded that these new materials offer great potential, but would require many years to develop. The challenge facing the U.S. industry, universities, and government is formidable. Within the government, mechanisms are in place to fund near-term product or military systems development and also long-term research at low level. These programs often take the form of basic research—either as single investigators or as ongoing efforts by centers of excellence. They can also lead to systems procurement, such as the Strategic Defense Initiative Office's program to develop superconducting magnetic energy storage devices.

However, approaches are needed for more intensive and accelerated programs and technologies that offer significant commercial potential, but which have been projected to be 10 and 20 years away from fruition. The Defense Advanced Research Projects Agency [DARPA] was formed 30 years ago to provide this function within the Defense Department. While DARPA programs are focused on military applications, they often result in civilian spinoffs, particularly in the areas of computer and materials development. Based on its experience in quick-response technology development, ongoing efforts in materials development, and highly integrated programs involving industries and universities, DARPA has identified superconductivity as a critically important technology area. DARPA'S superconducting program is technology-driven rather than basic research. The program comprises three areas: (1) synthesis, processing and fabricating of materials; (2) manufacturing issues; and (3) device development. HTSC materials must be fabricated into engineering sizes and shapes such as wires, coils, and thin films, and these materials must be optimized to have the proper properties such as tensile strength. Manufacturing issues include understanding the process control for reproducibly making,

with quality and quantity, the particular components we need, scale-up issues, and cost effectiveness.

Device demonstration will provide data for checking improvements in system performance and device development aspects oriented toward near-term retrofitting of present systems and also longer term designing of new materials that require changes in present technology.

To accomplish these tasks, teaming arrangements involving parallel research, design and manufacturing efforts are encouraged to expedite production of these new materials. Although this approach may result in additional expenses in the initial stages of the technology development, it can save significantly more money in the longer term by leading to more focused research projects that have increased manufacturing potential. It will also shorten the time to actually commercialize the products.

The DARPA superconductivity program is designed to develop this technology and it is applicable to both civilian and military systems. For example, DARPA coordinates its low-temperature or high-temperature work mostly with the Office of Naval Research, which emphasizes basic research. Our program, however, emphasizes material development and devices such as SQUIDs. SQUIDs are "Superconducting Quantum Interference Devices." And they can be used for systems both for civilian and military uses. For instance, in the case of civilian uses, it would include detecting magnetic fields within the brain. Or, in the case of military applications, it would be used for mine detection. Specific military applications will be developed independently of this particular DARPA program so that the whole program that we have can remain unclassified. Accurate and current information on these new materials is urgently needed if our contractors are to move ahead quickly. The superconducting effort includes a development of many components and devices. These include analog digital converters, analog devices, gyroscopes and accelerometers, digital computing devices, motors, bearings, SQUIDs, magnets and energy storage devices, radio frequency cavities and antennas and infrared sensors. Another important aspect of the program is thin film and bulk superconducting material development. This particular support group will address particular material processing problems and developing the proper properties, such as low mechanical strength, low current density and the high temperatures which are required for these materials to be processed. By addressing some of these important problems, hopefully we will be able to increase and help the people who are emphasizing the device development so that they can move on quicker.

This program includes large companies, such as Allied Signal, Hughes and General Electric, and includes a lot of small companies, particularly start-up companies Hypres, Biomagnetic Technologies, and Superconducting Technologies, Inc. Also many, many universities are involved: Cornell University, North Carolina, and Temple University are just three. We also have two centers that we are funding at the University of Houston, and a group of universities in Florida.

Specific milestones have been selected for each of the contractors, but I would like to mention just a few for the program as a

whole. We are interested ir pre-pilot plant production of pure superconducting power. Right now one of the largest supplies of power is a French company Ronpolu. We are interested in demonstration of 3 or a 50 HP superconducting electric motor. And we also intend to develop superconducting transistor-like devices which will be compatible with present day microelectronic technology. We hope to do all this in 3 years. The components and materials development in this program are of interest to the Strategic Defense Initiative Office, to the Services, and other agencies within the Defense Department and are coordinated with these groups for quicker transfer of this technology. We are also coordinated with DOE, NBS, NSF, NASA, and other government agencies.

Our program involves 33 contractors representing 22 companies, 6 universities and 5 government labs. There are 23 subcontractors from both universities and companies. And I have already mentioned the two university centers. The prime contractors are distributed across 15 states and the subcontractors, 6 additional states. Funding for this program is expected to be around $16.7 million, not including the centers. Of this, 72 percent of the funds will go directly to industry, 15 percent to the universities and 13 percent to government labs. Of the industrial spending, 44 percent will go to small businesses, and 50 percent will go to companies that traditionally do not participate in the Defense Department R&D program. We consider this to be a very, very good sign.

Although $28 million is needed for fiscal year 1989 to continue the present research programs, gaps still remain. This field is generating more innovative ideas for processing and device designs, as well as new materials, than present funding allows. A $50 million program is needed to accommodate new starts in fiscal year 1989 and the out years. These new starts should include developing superconducting support systems such as cryogenic cooling and high-temperature—rather, excuse me, high-strength superconducting composite material. Further work is also needed in lowering the temperature at which superconducting materials are processed, and we also need more design concepts.

There are two significant questions that arise concerning our program. One is, what if the yttrium barium cuprate material is not the right material? Another questions is, what if these materials do not lead significantly to improvements in present applications? Well, first, most of all our processing approaches under the development can be used for oxide or ceramic superconductors. Even if specific parameters such as the length of time for the oxygen anneal have to be changed and optimized, nevertheless this can still be transferred to the new material. This has already been demonstrated with the new bismuth and thallium-based superconductors that are now being studied. With all the potential these new materials exhibit, it is very difficult to believe that no applications will emerge in the next 10 to 15 years. Regardless, the DARPA program will generate spinoffs other than just ceramic superconductors, and will, I think, have an impact on materials technology across the board. It will provide U.S. companies, universities and agencies valuable experience in optimizing material properties and also in fabricating capabilities. These materials also possess in-

teresting magnetic and ferroelastic properties that could be developed for other applications.

So in closing, I would like to make several personal observations of the area. For the United States to be successful in developing high-temperature superconducting materials and devices, the government does in fact need to be involved. Consistent and reliable long-term funding at sufficient levels is essential and funds should be distributed throughout the government, not just DARPA. Various schemes should be considered to encourage research and development, including possible tax and capitalization incentives. Aggressive organizational approaches are also needed, including the establishment possible of a civilian DARPA, organization of a federal corporation or consortium such as SEMATECH or a Japanese-type MITI—Ministry of International Trade and Industry—or possibly a private corporation such as Superchip Corporation or possibly just a coordinated government effort. I would like to also say that in the short term, the government agencies are well-coordinated. We are well aware of the gaps that exist and any overlap in our programs is by design, not default. However, I am seriously concerned about the long-term, consistent, and reliable effort needed to actually commercialize these materials. For this reason, I feel that a Superconducting Oversight Committee is really desirable.

Although the DARPA investment in 1988 and thereafter will be sufficient, we have carefully chosen among the opportunities to define our priorities wisely. We have done a "top down" analysis, based on many conversations within industry concerning the ceramic materials forms we need such as tapes, wires and films and also the products that will be required—magnets, motors, transmission lines, microelectronic devices. We have also participated in the Defense Science Board Task Force on Military System Applications for Superconductivity to evaluate the greatest payoffs in the military applications for our national defense. However, to provide a strong national industrial technology base for manufacturing products as well as to provide the scientific underpinning for long-term growth, we really need cooperation and support from industry, universities and government.

Thank you for your time today.

[The prepared statement of Dr. Rhyne follows:]

DARPA's Approach to High-Temperature Superconducting Technology Development

In the recent National Academy of Sciences Report on High-Temperature Superconductors, the panel concluded that these new materials offer great potential, but would require many years to develop. The challenge facing U.S. industry, universities, and government is formidable. The mechanisms are in place to fund near-term product or military system development as well as lower level, long term research. These programs often take the form of basic research—either as a single investigation or as ongoing efforts by centers of excellence. They can also lead to systems procurement, such as the Strategic Defense Initiative Office's program to develop superconducting magnetic energy storage devices.

Approaches are needed for more intensive and accelerated development of technologies that offer significant commercial potential, but have been projected to 10 or 20 years away from fruition. The Defense Advanced Research Projects Agency [DARPA] was formed 30 years ago to provide this function within the Department of Defense. While DARPA programs are focused on military applications, they often result in civilian spinoffs, particularly in the areas of computer and materials development. Based on its experience in quick-response technology development, ongoing

efforts in materials development, and highly integrated programs involving industries and universities. DARPA has identified high-temperature superconductors [HTSCs] as a critically important technology area.

THE DARPA HTSC PROGRAM

DARPA's HTSC program is technology driven rather than basic research. The program comprises three areas: (1) synthesis, processing, and fabrication of materials; (2) manufacturing issues; and (3) device development. HTSC's must be fabricated into engineering sizes and shapes such as wires, coils, and thin films, each with optimized material properties (e.g. tensile strength). Manufacturing issues include understanding process control for a reproducible quality and quantity of HTSC components, scale-up issues and cost effectiveness. Device demonstration will provide data for checking improvements in system performance, while development aspects are oriented toward near-term retrofitting of present systems and longer term designing of new HTSC devices that may require changes in present systems technology.

To accomplish these tasks, teaming arrangements involving parallel research, design, and manufacturing efforts are encouraged to expedite production of HTSC components. Although this approach may result in additional expenses in the initial stages of technology development, it can save significantly more money in the longer term by leading to more focused research projects that have increased manufacturing potential.

The DARPA HTSC program is designed to develop a technology that is applicable to both civilian and military systems (see figure 1). For example, DARPA coordinates its HTSC work closely with the Office of Naval Research, which emphasizes basic research. The program emphasizes development of materials and devices such as SQUIDs (superconducting quantum interference devices.) SQUID's can be incorported into systems for civilian applications (e.g. detection of magnetic fields within the brain) or military applications (e.g. mine detection). The military applications will be developed independently of this DARPA program so it can remain unclassified. Accurate and current information on these new materials is urgently needed if the contractors are to move ahead quickly. The HTSC devices produced in these efforts will be used for large- and small-scale applications, and include: analog-to-digital (A/D) converters, analog devices, gyroscopes and accelerometers, digital computing devices, motors, bearings, SQUID's, magnets, and energy storage devices, radio frequency cavities and antennas, and infared sensors. Another critical aspect of the program is thin film and bulk HTSC materials development. The support group involved in this area addresses specific materials processing problems, such as low mechanical strength, low current density, and high temperatures at which the materials are processed. These studies will help other contractors concentrate on HTSC device development (see figure 2). A list of the prime contractors is given in figure 3. The various types of processing approaches are given in figure 4.

Specific milestones have been selected by each of the contractors and a few of these have been highlighted in figure 5. Many more accomplishments are expected from this program The components and materials development in this program are of interest to the Strategic Defense Initiative Office, Services, and other agencies within the Department of Defense, and coordinated efforts with these groups should allow for quicker transfer of technology (figure 6). A more detailed chart of Applications, Components, Processing/Fabrication, and Science is given in figure 7.

The DARPA HTSC program involves 33 prime contractors representing industry (22 companies), academia (6 universities), and government laboratories (5) laboratories); and 23 subcontractors, both companies and universities. The program also includes two university centers. The prime contractors are distributed across 15 states, the subcontractors, 6 additional states. Funding for the HTSC contracts let in fiscal years 1988 is $16.7 million, not including the centers. Seventy-two percent of the fiscal year 1988 funds will go to industries, 15 percent to universities, and 13 percent to government laboratories. Forty-four percent of the industrial funding is going to small businesses and 50 percent to companies that do not traditionally participate in DOD R&D programs.

Although $28 million is needed for fiscal year 1989 to continue the present program, gaps remain. This field is generating more innovative ideas for processing and device designs as well as materials than present funding allows. A $50 million per year program is needed to accommodate new starts in FY 89 or the outyears. These new starts would include developing superconducting support systems such as cryogenic cooling and high strength HTSC composite materials. Further work is needed in lowering the temperature at which HTSC materials are processed and device con-

cepts for HTSC three terminal like devices compatible with present micro electronics.

PROGRAMMATIC ISSUES

Two significant questions arise concerning the DARPA HTSC program:

What if the $YBa_2Cu_3O_7$ is not the right material?

What if such oxide materials do not lead to significant improvements in present applications?

Almost all of the processing approaches under development can be used for oxide or ceramic superconductors. Even if specific parameters such as the length of time for the oxygen anneal are changed and optimized, the approach can be transferred to the new material. This has already been demonstrated with the new Bismuth and Thallium based superconductors that are now being studied. With all the potential these new materials exhibit, it is difficult to believe that no application will emerge in the next 10 to 15 years. Regardless, the DARPA program will generate spinoffs other than ceramic superconductors that are important for materials technology. It will provide U.S. companies, universities, and agencies valuable experience in optimizing material properties and many fabricating capabilities. These materials also possess interesting magnetic and ferroelastic properties that could be developed for other applications.

CONCLUSIONS

For the United States to be successful in developing high-temperature superconducting materials and devices, the government needs to be involved. Consistent and reliable, long-term (10 years) funding at sufficient levels is essential and funds should be distributed throughout the government. Various schemes should be considered to encourage research and development including possible tax and capitalization incentives. Aggressive organizational approaches are also needed including, possible establishment of a civilian counterpart of DARPA, organization and participation in a Federal corporation or consortium (such as SEMETEC or a Japanese-type MITI—Ministry of International Trade and Industry) or a directed, coordinated government effort. Although the DARPA investment in fiscal year 1988 and thereafter will be significant, we will have to carefully chose among the opportunities and define our priorities wisely. We have done a "top down" analysis, based on many conversations with industry, of the ceramic materials forms we need—tapes, wires, thin films—for the products that are required—magnets, motors, transmission lines, microelectronic devices. We have participated in the Defense Science Board Task Force on Military System Applications of Superconductors to evaluate the greatest payoffs in military applications for our National Security. However, to provide a strong national industrial technology base for manufacturing products, as well as to provide the scientific underpinning for long term growth, we will need the cooperation and support of both industry and Government.

Mr. ROE. Thank you very much. Dr. Notis?

STATEMENT OF PROF. MICHAEL R. NOTIS, DEPARTMENT OF MATERIALS SCIENCE AND ENGINEERING, LEHIGH UNIVERSITY, BETHLEHEM, PA

Dr. NOTIS. I would like to thank the Chairman for the opportunity to testify today on a subject that I consider critical to the future development and growth of science and technology in the United States. I will divide my remarks into three focus areas:

First, to describe my own research, together with that of my colleagues, related to the development of superconducting composite ceramic wire.

Second, to describe the Lehigh University Consortium on Superconducting Ceramics, the first such consortium formed between industry, government laboratories and university.

Lastly, to say something more general about U.S. funding of research for high temperature superconductivity, especially in relation to that of other countries such as Japan.

I might say, my presentation is just a few minutes longer than most of the others so far, so if you will please bear with me.

Anyone who has picked up a newspaper or a magazine recently is aware of the breakthroughs being achieved in the field of superconducting materials. Great excitement has been generated by the promise that these new materials hold. Although the existence of superconductivity has been known since the beginning of the century, until recently superconducting materials had to be cooled to prohibitively low temperatures before exhibiting such behavior. The discovery of "high-temperature" superconductivity, that is, with a transition temperature near or above the boiling point of liquid nitrogen, now makes possible a myriad of new applications for superconductivity and even new technologies previously not considered feasible.

The pace of research in the area of ceramic superconducting materials has been incredible. Researchers all over the world have made significant discoveries of new materials with higher and higher critical temperatures. Almost all of the materials discovered so far have been composed of elements such as lanthanum, yttrium, bismuth, thallium, strontium and calcium, in combination with copper and oxygen. These cuprates all possess a fairly complicated non-cubic structure based on a class of crystal structures known as the perovskites. Recently, a non-cuprate cubic perovskite superconductor has been reported by workers at AT&T. This material has significant implication for future development. Many other research groups have been concerned with the program of the low—or poor—values of critical transport time that these superconducting ceramic materials presently possess. At Lehigh, I have been involved with research, together with Profs. Betzalel Avitzur and Himanshu Jain, to try to fabricate these new ceramic superconductors into a composite wire configuration. This work has been funded by a small grant from the National Science Foundation and from the Lehigh University Consortium on Superconducting Ceramics [LUCSC], which I will describe later.

One of the most desirable configurations for a useful superconductor is as a wire product. In this form it is useful as a conductor for DC or AC power transmission, and for the generation of high magnetic fields. The production of fine wire is critical to minimize problems with stabilization and to lower the AC or dynamic losses associated with changing field. If ceramic superconductors can be fabricated in a wire configuration, its potential for commercialization is considerable over a broad industrial spectrum, and this commercialization might be accomplished much earlier than if other forms, for example, thin films, of ceramic superconductors are required. For this reason, much research related to the fabrication of ceramic superconducting wire has already been performed.

Wire can be fabricated either by wire drawing or extrusion. Wire drawing is a more economical and commercially desirable process because it can be easily made into a continuous operation. On the other hand, hydrostatic extrusion often allows for easy separation of experimental variables and is therefore a great benefit for fundamental studies or for situations where wire drawing is just not feasible. In our research, two different configurations for a composite ceramic wire have been used. In the first piece that I gave you,

we have used a thick wall silver tube with a variety of cuprate superconducting ceramic powders packed inside; so far we have used this configuration with our experiments on wire fabrication by hydrostatic extrusion. This composite has been demonstrated to be in the superconducting state after final fabrication, by levitation testing over a magnet submersed in liquid nitrogen, and by direct transport measurements. The other configuration we have used has consisted of a thin wall silver tube containing the superconducting ceramic powder, both of which are placed inside a thick wall tube made of either stainless steel, nickel, or cooper. The higher strength outer material makes the assembly more amenable to wire drawing because of the higher wire pulling load that can be applied. Here also, the out tube may be removed after wire drawing for further processing. However, after interim annealing operations, these composites have shown significant reaction between the superconductor and the outer tube material, right through the thin silver interlayer. This has significant implication for the future development of commercial wire products, for fabrication of multifilamentary wires, and for joining technology in general. A major part of our current research is focused on the development of methods and the selection of materials that would eliminate this detrimental reaction.

I would now like to turn to some of the funding issues related to superconducting ceramic research, for the amount and nature of the available funding support is critical to the ultimate success of this area of technology. Some of my colleagues at Lehigh have been concerned with superconducting ceramics for many years; for example, Professor Avitzur has been sponsored by the Department of Energy for his research on composite metal wires for high-field magnetic applications.

However, research with the new ceramic superconductors requires expertise in many different areas including powder preparation, microstructure characterization, fabrication techniques, physical property measurement, etc. Too much of the research work performed so far has been done on poorly characterized material obtained from relatively non-reproducible production methods; much of this work will have to be repeated under better laboratory conditions.

At Lehigh, we have been aggressive in terms of our desire to overcome many of these problems through the formation of a consortium in this research area. As you may know, Congressman Ritter has been a strong proponent of consortia for superconductivity research and we are particularly thankful for his help in the initiation of our own program.

The Lehigh University Consortium on Superconducting Ceramics [LUCSC] is currently composed of 11 industrial corporations and government laboratories who provide funding to our university. Some of these companies have been involved with research in superconductivity for many years; others are newcomers to the field. This funding is matched to a significant degree by the state of Pennsylvania's Ben Franklin Partnership Program. In all, the consortium has operated during the past year with about $400,000 in funding. These funds have been used to develop central laboratories for superconducting ceramic powder preparation and charac-

terization, and for physical property measurements; and to perform specific research projects related to fabrication of superconducting wire, tape casting, development of high critical current density, solid state chemistry, microstructural studies, high frequency measurements and ultrasonic measurement of the elastic behavior of superconductors. The availability of these funds has enabled the growth of a strong interdisciplinary character to our research. The consortia arrangement has enabled us to interact with members of the industrial and government laboratory communities and has had significant influence on the perception of our own research work. We hope that it enhances technology transfer and commercialization in the future.

Despite our initial success, as we are negotiating for the second year funding for the operation of the consortia, we are experiencing some problems. This is due mainly to funding difficulties encountered by our government laboratory members relating to a general DOD freeze on all R&D commitments, and to the realization by one or two industrial members that the development of useful applications of superconductive materials will not take place in a short period to time.

When the new high-Tc superconductors were first discovered, there was much hope and speculation that they could be moved quickly into the marketplace. This has proved not to be true and correspondingly the intensity of interest has to some extent decreased. I would, therefore, like to comment on my views concerning the need for long-term focused government support of research in superconductivity.

In July of 1987, at a conference on superconductivity in Washington, DC, President Reagan announced a broad Federal program an "eleven-point superconductivity initiative"—to promote research and speed commercial development. Congressmen David McCurdy and Don Ritter have both introduced bills related to superconductivity, originally calling for funding in fiscal 1989. These bills have been merged into compromise legislation with funding probably not until 1990. We are, therefore, already one year off our original target. As pointed out by Congressman Ritter, the DARPA program for superconductor manufacturing and processing technology is badly underfunded because of other budgetary pressures. I am also concerned about the nature of the DARPA program itself. It is not clear how the research findings from this program will be disseminated to the general science community and to industry. DARPA's work is unclassified but there has been little information on the research being performed by the industrial groups being supported through the program.

Except for the DARPA-DOD program, little new funding has actually come through for superconductivity research. Instead, Federal agencies continue to reallocate funds from other budget areas. This has caused a number of problems. For example, the Materials Research Division of NSF requested a 9.8 percent increase for fiscal 1988. It received a 1.8 percent increase. The Low Temperature Physics Program, which funded Paul Chu's work, requested a 10 percent increase for 1988. It received a 2.5 percent increase. Other previously funded grants within the Division were asked to cut their existing funding by 10 percent. The real increase in funds

into the Low-Temperature Physics Program was small, and the Program Director has left the Foundation. The existing non-superconductivity research work is now underfunded and these researchers are feeling the pressure. As well, program managers in other agencies who also operate with a peer review system find that because of the rapid pace of research in this area, the superconductivity research that had been proposed has already been performed by the investigator or by another research laboratory by the time the peer review process is complete. We must find new ways to plan and fund research in an environment which moves with the rapid pace we have in today's world.

Finally, I would like to make some comments comparing our R&D situation to that of other countries, in particular, to that of Japan.

American businessmen are often frustrated by the propensity of Japanese for prolonged and detailed negotiation over contractural agreements and the time-consuming group consensus approach that they take. However, once the plans and negotiations are successfully completed, the Japanese dedicate themselves fully to the project and are prepared for long-term commitment. Therefore, even though the Japanese may not be the first to develop and market a product, they have a great ability to know when to become involved, and once in the game, they have great endurance. The Japanese approach to scientific and technological research is similar. Good planning and a national policy with focused goals activates and commits the entire industrial system to a long-term effort for success. The Japanese approach to commercialization is also unique. Small products, sometimes demonstrating only trivial aspects of a new technology, are introduced into the marketplace with high consumer visibility. A large number of such products gives industry broad experience dealing with the new technology as a whole, while at the same time building a strong consumer base.

An excellent example of this entire process is the introduction of "fine" or high-technology ceramics in Japan during the last decade. Japan has a long history and large industry based related to traditional ceramic manufacture. Although in general Japan is a resource-poor country, the raw materials from which ceramics are made are available. In order to take advantage of the perceived future growth in ceramics and other new materials, MITI sponsored a major national effort of the development of fine ceramics. Although large corporations play a major role in this development area, Government Industrial Research Institutes provide R&D guidance and direct development assistance for new products to small companies without R&D facilities. Fine ceramics have been introduced early into the marketplace by the fabrication of zirconia and silicon nitride scissors, hammers, golf clubs, knives—some which I have put up on the table—all available in department stores throughout Japan. A ceramic turbocharger rotor blade is now available on at least one make of Japanese sports car. Japanese firms now dominate the world on ceramic packages for electronic devices.

The approach of the Japanese to develop and commercialize high-Tc superconductivity as a broad technology has been even more intense. Japan has already gotten a good start in this field,

perhaps at an earlier stage then in the past. The Japanese have already successfully demonstrated a magnetically levitated vehicle, the original concept for which was developed in the United States. With the discovery of the new high-Tc superconducting materials, major Japanese companies have already filed over 2,000 patents. Japan's research budget for superconductivity in 1988 is as large as that of the United States, approximately $55 million. For example, to break it down, the Science and Technology Agency (STA) has allocated $19 million for superconductivity research under a program that they call the "Multi-core Research Project," and an additional $22 million for future general energy research. While MITI is devoting $20 million to research focused on efforts to develop superconductive wire and highly efficient electrical systems, even larger programs are being discussed, for example, a joint MITI-Kansai Electric Power Co. project to build a 200 MW generator using high-Tc superconductors—cost $200 million—to be completed in 1996. MITI also sponsors the International Superconducivity Technology Center to which about 90 Japanese companies belong. ISTEC is building a research laboratory to which 44 major companies have contributed about $800,000 each and will share in the research findings. ISTEC is sponsoring its first international meeting in Nagoya in late August of this year as a showcase of the research work already performed by industry and government in Japan. In terms of commercialization, many companies, like Hayashi, have marketed superconducting powders, the total sales of which are significantly larger than in the United States. And simple wire products are now being made by Sanyo, Sumitomo, and Fujikura. Hitachi has succeeded in the trial manufacture of a Josephson Junction fluxmeter fabricated from high-Tc superconducting thin films by photolithographic techniques and which operates in liquid nitrogen. Sharp reports the production of a magnetic sensor using a sintered ceramic high-Tc superconductor. Other companies that have announced superconducting products include Fujitsu, Kyocera, Matsushita, Mutsui, Toshiba and Nippon Electric.

It is imperative for industry, university and government agencies in the United States to work together to develop a meaningful long range research program and real commitment in this area. The negative mindset that we have established vis-a-vis Japanese technology in general must be overcome. Programs such as SEMATECH and the proposed Ritter/McCurdy compromise legislation will help significantly to push us in the right direction.

Thank you.

[The prepared statement of Dr. Notis follows:]

"A UNIVERSITY VIEW OF SUPERCONDUCTIVITY RESEARCH"

TESTIMONY OF

PROFESSOR MICHAEL R. NOTIS

DEPARTMENT OF MATERIALS SCIENCE AND ENGINEERING

452 WHITAKER LABORATORY

LEHIGH UNIVERSITY

BETHLEHEM, PA 18015

to the

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

U. S. HOUSE OF REPRESENTATIVES

SUBCOMMITTEE ON INVESTIGATIONS AND OVERSIGHT

Hearing on

THE CUTTING EDGE: SCIENCE AND TECHNOLOGY for AMERICA'S FUTURE

PANEL on SUPERCONDUCTIVITY

June 27, 1988, Monday

11:30 - 3:30PM

MARTIN TOWERS AUDITORIUM

BETHLEHEM STEEL CORPORATION

BETHLEHEM, PA 18018

"A UNIVERSITY VIEW OF SUPERCONDUCTIVITY RESEARCH"

Michael R. Notis

I'd like to thank the chairman for the opportunity to testify today on a subject that I consider critical to the future development and growth of science and technology in the United States. I will divide my remarks into three focus areas:

1. First, to describe my own research, together with that of my colleagues, related to the development of superconducting composite ceramic wire.
2. Second, to describe the Lehigh University Consortium on Superconducting Ceramics, the first such consortium formed between industry, government laboratories and university.
3. Lastly, to say something more general about U.S. funding of research for high temperature superconductivity, especially in relation to that of other countries such as Japan.

Anyone who has picked up a newspaper or magazine recently is aware of the breakthroughs being achieved in the field of superconducting materials. Great excitement has been generated by the promise that these new materials hold. Although the existence of superconductivity has been known since the beginning of the century, until recently superconducting materials had to be cooled to prohibitively low temperatures before exhibiting such behavior. The discovery of

"high-temperature" superconductivity, i.e., with a transition temperature near or above the boiling point of liquid nitrogen, now makes possible a myriad of new applications for superconductivity and even new technologies previously not considered feasible.

The pace of research in the area of ceramic superconducting materials has been incredible. Researchers all over the world have made significant discoveries of new materials with higher and higher critical temperatures (T_c); almost all of the materials discovered so far have been composed of elements such as lanthanum, yttrium, bismuth, thallium, strontium, and calcium, in combination with copper and oxygen. These cuprates all possess a fairly complicated non-cubic structure based on a class of crystal structures known as Perovskites. Recently, a non-cuprate cubic Perovskite superconductor has been reported by workers at AT&T; this material has significant implication for future development. Many other research groups have been concerned with the problem of the low (poor) values of critical transport current (J_c) that these superconducting ceramic materials presently possess. At Lehigh, I have been involved with research, together with Professors Betzalel Avitzur and Himanshu Jain, to try to fabricate these new ceramic superconductors into a composite wire configuration. This work has been funded by a small grant from the National Science Foundation and from the Lehigh University Consortium on Superconducting Ceramics (LUCSC), which I will describe later.

One of the most desirable configurations for a useful superconductor is as a wire product. In this form it is useful as a conductor for DC or AC power transmission, and for the generation of high magnetic fields. The production of fine wire is critical to

minimize problems with stabilization and to lower the AC or dynamic losses associated with changing field. If ceramic superconductors can be fabricated in a wire configuration, its potential for commercialization is considerable over a broad industrial spectrum, and this commercialization might be accomplished much earlier than if other forms, i.e. thin films, of ceramic superconductors are required. For this reason, much research related to the fabrication of ceramic superconducting wire has already been performed.

The various approaches to the fabrication of ceramic wire can be subdivided into three geometric categories: (1) bare wire, (2) metal-core-composite wire, or (3) metal-clad composite wire (powder-in-tube). So far, none of these approaches have produced wire with J_c high enough to be of interest for the desired applications. However, experiments with fibers made by melt-textured-growth have produced major improvement in J_c. These improvements are attributed to proper preferred orientation, formation of a dense structure, and the formation of fewer and cleaner grain boundaries. It is therefore likely that wire processing that would include provision for these characteristics should produce greatly improved properties.

The methods used so far for the fabrication of bare ceramic wire require the use of an organic binder; however, the barium-yttrium-copper ("1-2-3") superconductors of most common use today are believed to be degraded by carbon contamination. The metal-core-composite wire leaves the ceramic superconductor exposed to reaction with the CO_2 in the atmosphere, and the geometry is such to put the brittle material furthest from the central-axis thus making it more susceptible to cracking due to bending. We have therefore chosen to use the metal-clad

composite wire configuration for our experiments. In this configuration, it has already been shown that the superconductor can be fabricated using silver as the tube material. Silver is non-reactive with respect to the cuprate superconductors but allows for rapid oxygen diffusion. Further, silver or silver oxide can be incorporated into the cuprate matrix, possibly enhancing ductility and providing a source of oxygen.

Wire can be fabricated either by wire drawing or by extrusion. Wire drawing is a more economical and commercially desirable process because it can be easily made into a continuous operation. On the other hand hydrostatic extrusion often allows for easy separation of experimental variables and is therefore of great benefit for fundamental studies or for situations where wire drawing is just not suitable. In our research, two different configurations for a composite ceramic wire have been used. In one case, we have used a thick wall silver tube with a variety of cuprate superconducting ceramic powders packed inside; so far we have used this configuration with our experiments on wire fabrication by hydrostatic extrusion. This composite has been demonstrated to be in the superconducting state after final fabrication by levitation testing over a magnet submersed in liquid nitrogen; we are now in the process of making direct transport measurements. The other configuration we have used has consisted of a thin wall silver tube containing the superconducting ceramic powder, both of which are placed inside a thick wall tube made of either stainless steel, nickel, or copper. The higher strength outer material makes the assembly more amenable to wire drawing because of the higher wire pulling load that can be applied. Here also, the outer tube may be removed after wire

drawing for further processing. However, after interim annealing operations, these composites have shown significant reaction between the superconductor and the outer tube material, right through the thin silver interlayer. This has significant implication for the future development of commercial wire products, for fabrication of multifilamentary wires, and for joining technology in general. A major part of our current research is focussed on the development of methods and the selection of materials that would eliminate this detrimental reaction.

I would now like to turn to some of the funding issues related to superconducting ceramic research, for the amount and nature of the available funding support is critical to the ultimate success of this area of technology. Some of my colleagues at Lehigh have been concerned with superconducting materials for many years; for example, Professor Avitzur has been sponsored by the Department of Energy for his research on composite metal wires for high-field magnetic applications. However, research with the new ceramic superconductors requires expertise in many different areas including powder preparation, microstructure characterization, fabrication techniques, physical property measurement, etc. Too much of the research work performed so far has been done on poorly characterized material obtained from relatively non-reproducible production methods; much of this work will have to be repeated under better laboratory conditions.

At Lehigh, we have been aggressive in terms of our desire to overcome many of these problems through the formation of a consortium in this research area. As you may know, Congressman Ritter has been a strong proponent of consortia for superconductivity research and we are particularly thankful for his help in the initiation of our own program.

The Lehigh University Consortium on Superconducting Ceramics (LUCSC) is currently composed of eleven industrial corporations and government laboratories who provide funding to our university. Some of these companies have been involved with research in superconductivity for many years, others are newcomers to the field. This funding is matched to a significant degree by the State of Pennsylvania'a Ben Franklin Partnership Program. In all, LUCSC has operated during the past year with about $400,000.00 in funding. These funds have been used to develop central laboratories for superconducting ceramic powder preparation and characterization, and for physical property measurements; and to perform specific research projects related to: fabrication of superconducting wire, tape casting, development of high critical current density, solid state chemistry, microstructural studies, high frequency measurements and ultrasonic measurement of the elastic behavior of superconductors. The availability of these funds has enabled the growth of a strong interdisciplinary character to our research. The consortial arrangement has enabled us to interact with members of the industrial and government laboratory communities and has had significant influence on the perception of our own research work. We hope that it enhances technology transfer and commercialization in the future.

Despite our initial success, as we are negotiating for the second year funding for the operation of LUCSC, we are experiencing some problems. This is due mainly to funding difficulties encountered by our government laboratory members relating to a general DOD freeze on all R & D commitments, and to the realization by one or two industrial members that the development of useful applications of superconductive materials will not take place in a short period of time.

When the new high T_c superconductors were first discovered, there was much hope and speculation that they could be moved quickly into the marketplace. This has proved not to be true and correspondingly the intensity of interest has to some extent decreased. I would therefore like to comment on my views concerning the need for long term focused government support of research in superconductivity.

In July of 1987, at a conference on superconductivity in Washington, DC., President Reagan announced a broad federal program - an "11-point superconductivity initiative" - to promote research and speed commercial development. Congressmen Dave McCurdy (D-OK) and Don Ritter (R-PA) have both introduced bills related to superconductivity, originally calling for funding in fiscal 1989; these bills have been merged into compromise legislation (H.R. 3048) but with funding probably not until fiscal 1990. We are therefore already one year off our original target. As pointed out by Congressman Ritter, the Defense Advanced Research Project Agency (DARPA) program for superconductor manufacturing and processing technology is badly underfunded because of other budgetary pressures. I am also concerned about the nature of the DARPA program itself. It is not clear how the research findings from this program will be disseminated to the general science community and to industry. DARPA's work is presumably unclassified but there has been little information on the research being performed by the industrial groups being supported through the program.

Except for the DARPA-DOD program, no new funding has actually come through for superconductivity research. Instead, federal agencies continue to reallocate funds from other budget areas. This has caused a number of problems. For example, the Materials Research Division of NSF

requested a 9.8% increase for fiscal 1988, it received a 1.8% increase; the Low Temperature Physics Program, which funded Paul Chu's work, requested a 10.0% increase. for fiscal 1988, it received a 2.5% increase. Other previously funded grants with the Division were asked to cut their existing funding by 10%. The real increase in funds into the Low Temperature Physics Program was small and the program director has left the Foundation. The existing non-superconductivity research work is now underfunded and these researchers are feeling the pressure. As well, program managers in other agencies who also operate with a peer review system, find that, because of the rapid pace of research in this area, the superconductivity research that had been proposed has already been performed by the investigator or by another research laboratory by the time the peer review process is complete. We must find new ways to plan and fund research in an environment which moves with the rapid pace we have in today's world.

Finally, I would like to make some comments comparing our R & D situation to that of other countries; in particular, to that in Japan.

American businessmen are often frustrated by the propensity of the Japanese for prolonged and detailed negotiation over contractural agreements and the time consuming group consensus approach that they take. However, once the plans and negotiations are successfully completed, the Japanese dedicate themselves fully to the project and are prepared for long term commitment. Therefore, even though the Japanese may not be first to develop and market a product, they have a great ability to know when to become involved, and once in the game they have great endurance. The Japanese approach to scientific and technological research is similar. Good planning and a national policy with focused

goals activates and commits the entire industrial system to a long term effort for success. The Japanese approach to commercialization is also unique. Small products, sometimes demonstrating only trivial aspects of a new technology, are introduced into the marketplace with high consumer visibility. A large number of such products gives industry broad experience dealing with the new technology as a whole, while at the same time building a strong consumer base.

An excellent example of this entire process is the introduction of 'fine' or high-technology ceramics in Japan during the last decade. Japan has a long history and large industry base related to traditional ceramic manufacture. Although, in general, Japan is a resource poor country, the raw materials from which ceramics are made are available. In order to take advantage of the perceived future growth in ceramics and other new materials, MITI (Ministry of International Trade & Industry) sponsored a major national effort for the development of fine ceramics. Although large corporations play a major role in this development area, GIRI (Government Industrial Research Institutes) provide R & D guidance and direct development assistance for new products to small companies without R & D facilities. Fine ceramics have been introduced early into the marketplace by the fabrication of zirconia and silicon nitride scissors, hammers, golf clubs, and knives, all available in department stores throughout Japan. A ceramic turbocharger rotor blade is now available on at least one make of Japanese sports car.

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earlier stage then in the past. The Japanese have already successfully demonstrated a magnetically levitated vehicle, the original concept for which was developed in the U.S. With the discovery of the new high-T_c superconducting materials, major Japanese companies have already filed over 2,000 patents. Japan's research budget for superconductivity in 1988 is as large as that of the U.S. (approximately $55 million); the Science and Technology Agency (STA) has allocated $19 million for superconductivity research (Multi-core Research Project) and an additional $22 million for future energy research, while MITI is devoting $20 million to research focused on efforts to develop superconductive wire and highly efficient electrical systems. Even larger programs are being discussed, for example, a joint MITI - Kansai Electric Power Company project to build a 200 MW generator using high T_c superconductors (cost $200 million) to be completed in 1996. MITI also sponsors the International Superconductivity Technology Center (ISTEC) to which about 90 Japanese companies belong. ISTEC is building a research laboratory to which 44 major companies have contributed about $800,000 each and will share in the research findings. ISTEC is sponsoring its first international meeting in Nagoya in late August of this year as a showcase of the research work already performed by industry and government in Japan. In terms of commercialization, many companies (ex., Hayashi) have marketed superconducting powders (total sales of which are significantly larger then in the U.S.), and simple wire products (Sanyo, Sumitomo, and Fujikura). Hitachi has succeeded in the trial manufacture of a Josephson Junction fluxmeter fabricated from high T_c superconducting thin films by photolithographic techniques and which operates in liquid nitrogen. Sharp reports the production of a

magnetic sensor using a sintered ceramic high T_c superconductor. Other companies that have announced superconducting products include Fujitsu, Kyocera, Matsushita, Mitsui, Toshiba and Nippon Electric.

It is imperative for industry, university and government agencies in the U.S. to work together to develop a meaningful long range research program and real commitment in this area. The negative mindset that we have established vis-a-vis Japanese technology in general must be overcome. Programs such as sematech and the proposed Ritter/McCurdy compromise legislation (H.R.3048) will help significantly to push us in the right direction.

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Mr. ROE. OK. Dr. Rhyne, you mentioned one point as we went along about an oversight committee. What were you thinking about there?

Dr. RHYNE. Something needs to be done to not just coordinate, I think, but also make sure that we stay the course within the various departments and agencies. I think that is sometimes overlooked.

Mr. ROE. Do you have any specifics in mind?

Dr. RHYNE. No, not at all.

Mr. ROE. But you are saying there should be some oversight committee in some House and Senate Committee that looks and watches over.

Dr. RHYNE. Yes, I think there are a lot of different ideas proposed, OSTP maybe having a more significant role, such as wisemen staying on permanently in some form or the National Materials Council—there is a wide variety of—a superconducting czar has been suggested, an advocate, champion, helper. I think there is a lot of different possibilities here. I am not absolutely sure which one. I would agree with the comments made earlier that I do not think they should regulate, but that certainly something needs to be done to make sure that each of the departments stay the course.

Mr. ROE. Dr. Notis expresses concern that new discoveries in DARPA's program will not be transferred to other researchers. Will you reassure him that there will be no competitiveness to information dissemination?

Dr. RHYNE. I can assure him to the best that I can make of it that will be the case. I think the setup now—besides being unclassified, we would also like to see this open to the public. There will be reports—people will be presenting papers at conferences. So I do not see any impediment at this time.

Mr. ROE. What was your observation, Dr. Notis?

Dr. NOTIS. Believe me, I do not mean that DARPA will not disseminate this information. I just think that in the setting of the current research problem that we have, that the bureaucratic systems that are necessarily set up to disseminate information, the same way the publications and journals in this area do not adequately keep up with the research that is going on, I think that the methodology by which information is going to be disseminated has to be even faster than the normal routines that would normally be followed. That is going to be a problem.

Mr. ROE. We are concerned about the program—the eleven-point program, you both spoke about that. That is the $150 million over the 3-year period. And of course, with the—I was thinking about the DOD has placed a freeze on R&D contracts?

Dr. RHYNE. Yes.

Mr. ROE. But only—but would only have 75 percent. What do you see on that?

Dr. RHYNE. Well, the directive was put in place May 20. That is my understanding as of last Friday. This directive is being modified July lst to allow 75 percent of the contracts basically to get through. Priority is given to small businesses, minorities and those that have been held up over this last 6-week period. The discretion about which program can actually make it through is left up to the agency heads. In the case, that would be Dr. Ray Colladay, head of

DARPA. He has told me as of Friday afternoon that the whole superconductivity program will in fact go through.

Mr. ROE. Where is it——

Dr. RHYNE. It is part of the 75 percent.

Mr. ROE. What about this report, Dr. Rhyne, that is coming out from OTA; they say that they believe the effort is unfocused, has not built a solid foundation for future commercialization?

Dr. RHYNE. Which, the DARPA program or the superconductivity?

Mr. ROE. As I understand it, superconductivity initiative. I do not think he is speaking about DARPA per se, across the board.

Dr. RHYNE. I guess it is pretty much up to the agencies, and each of the agencies has different priorities, different missions, again similar kind of promises with manufacturing involved.

Mr. ROE. So basically what we are saying again if it is going to stay on this course, we have got to consider a national policy, we ought to start making national policy in the first place and coordinate what we are doing basically?

Dr. RHYNE. Exactly.

Mr. ROE. Mr. Ritter.

Mr. RITTER. Thank you, Mr. Chairman. I want to thank both of you here for your testimony, and I want to particularly focus right in on some of the things you said, Dr. Notis. I understood from the tone of your voice, there is some alarm—you feel some alarm that this thing is getting away from us—that we essentially started up at the same time, the basic information flowed worldwide immediately, and yet the competition who has beaten us after 20 years in semiconductors and beaten us in consumer electronics after 20 years, these are leaps—is really out of the starting gates fast. Is that a correct impression? That you are expressing some alarm?

Dr. NOTIS. Certainly the large portion of the research that is done—that has been done so far, come into the literature so far has been freebies from people in university research or industrial research who had been quick to move into the superconductivity area by sheer desire, by individual initiative. And what is happening now, is that as the technology is starting to come slowly, developments are starting to slow down, that is expected to be replaced by government funding and a more stable environment. The Japanese have been much quicker to put into the system that kind of funding to keep the initial initiative and drive going. And so, if we do not keep stoking the fires, if you would, then I think we are in fact going to find ourselves at a difficult position with respect to the Japanese. I think that in fact if I would compare what I see coming out of the literature, technologically, fundamentally from the Japanese, I do not think it is very, very different from the United States. I think that the international science community is truly international at this point, and information is distributed very, very rapidly.

Mr. RITTER. The science part—what about the technology and the product development that is the science part?

Dr. NOTIS. I think there, due to the organization of Japanese industry, government agencies, now together with universities—and that was the poor link before—they are much—they have better ability to react more quickly to the situation than we do. For exam-

ple, we have no long-range national science policy. Our policy changes every four years with the administration, whether the political party changes or not. Their system is such that it is decoupled from the political system to a very large extent. It has stability. The industry itself is more focused towards long-term profits rather than short-term, and Japanese industry protects itself. We normally fight with both hands tied behind our backs. And in this case, I think it would be a terrible situation if we continue to do that.

Mr. RITTER. Yes. Are you familiar with the "Wall Street Journal" front page lead story on April 29—I guess you mentioned it, "The 90 Companies," reads likes a "Who's Who" of Japan's industry. It was the lead story in the "Wall Street Journal" front page—$825,000 each, $125,000 annual contribution after the initiation fee. The OTA report I think is selling us a very potent message. The OTA report says "[t]hat unless the United States really puts its act together," and they are talking about a program, probably the government is involved from a $100 to $500 million, where the industry is involved heavily, that given the Japanese penchant for developing technology and products over the next 10 years which—we are just going to lose it. I think this is one of the most—talk about that Olympic race, that is economic Olympics. High-temperature superconductivity is a symbol of that race, because we are kind of both starting at the same time. But also beyond the symbol, we have had such tremendous implications for the way we live and work. It involves the very essence of our modern technology which is electricity, and how you transmit electricity. But I am not saying—I am thinking that we do not have the message across the length of the country. In other words, we had it for a few months and all the magazine articles appeared, and as soon as the magazine articles stopped appearing, as soon as the crucial critical breakthroughs, we went back to business as usual. We are not doing the job, in my own opinion. My own administration came forth with a wonderful program that has not been on the front burner. I am really concerned that we could lose it at the cutting edge of the Japanese.

Dr. RHYNE. I would like to make a couple comments too to add to that.

Mr. RITTER. Dr. Rhyne.

Dr. RHYNE. Thank you. I think that we have a lot to offer, too. I am very concerned as well for the reasons you mentioned. First of all, we are behind in the ceramic processing much further than the Japanese.

Mr. RITTER. I think 10 years they have been focusing on that.

Dr. RHYNE. That is right. So we are coming back actually from behind rather than breaking even. We do not have the mechanism, the models that are tried and true of how government can get things done in an efficient, effective manner and very quickly. These are all lacking, but I think this also offers us the opportunity to try and implement these things. I think there is a greater awareness of technology as well as basic research has to be done in a somewhat parallel situation. So I think we are—I think that there is great opportunities as well as great dangers that lie here.

Mr. RITTER. The symbol in Chinese is similar for opportunity and danger. And I think that is where we are with superconductivity.

Mr. ROE. Let me respond. This goes back—that is the advantage of being a little less under pressure as we are today. That goes back to the first panel. And one of the discussions that we had with the members of the first panel, both industry and academia, was based upon the point of view of other government policies, other than the gung-ho point of being productive, is shaping the direction we are going in, is really working enormous counter-force to what we are talking about, improved competitiveness. For example, we spent $1 billion of the Clinch breeder reactor, had the materials all fabricated in warehouses, and we simply just canceled the program. A billion dollars was spent on that program. We are no longer interested in it anymore, okay.

You talk about, Dr. Notis, that every 4 years, you could not be more correct in that point. Every 4 years, the policy changes. There is not any policy. The factor that we have been fighting over the last 2 years, particularly on the Superconducting Supercollider, really triggered the issue of "small science" versus "big science." You know the mega-bucks related to large issues. And that came up by the way in an earlier session we had today. And the question was asked, "well, how do you feel?" You know we hear from the professors from the different universities, you will pardon the reference, and they come back and scream bloody murder on the point of—we should not be doing this, we should not be doing that, we should be looking for the basic research because the basic research is the thing that is going to lead to where we are supposed to go.

Now, having said all of that, one has got to come back and say, that out of that argument raises the point of what are or are there any priorities as far as the scientific community is concerned, not just government alone? It is not government that is calling all the shots. The so called "peer review" issue—and that I do not want to get into today, because that will set me off at this particular point. What I am coming back and saying is, we do not have a national science policy or program in our Congress or in your administration and not only this administration, the one before it. And where Don and I have been working on—we have had to, and I meant this admonishment publicly today—we have had to devote our energies and I am talking on our own intellectual energies to saving and rebuilding, restructuring the space program—without that we would not have anything—we would have gone down the tubes. It is a battle that we fought from—and it is still not over. It has been extraordinary to try to keep that program alive.

Therefore, we have not be able to give the energies and resources to what we would like to be doing in superconductivity, also in biotechnology, by the way. But we have drawn attention to the nation the debate on the Superconducting Supercollider. That I think we have done, and we have done that successfully. We had that vote on the floor the other day, and I think there were only 26 negative votes against that whole program.

Mr. RITTER. That was the authorization.

Mr. ROE. The authorization. The whole bill together, we got to see what happens to that eventually. Where I am coming from, and

without being too loquacious, trying not to be, is that unless we narrow down a specific direction that institutionally can survive a 2-year Congress and a 4-year Presidency and a 6-year Senate, unless we narrow it down to some direction, all of the flapping of arms are not going to make any difference. You are working on the point of the $150 million program that the President has suggested, now they come back and say too bad you got to cut that back, they are not going to do that. You just cannot do that and get anything done practically.

Dr. RHYNE. Well, in this particular case we had over 16 companies, industries working at risk because we had given them an early start pending the negotiating—the conclusion of negotiations, and everything came to a screeching halt with the tax directive.

Mr. ROE. If we had not won the battle on the floor the other day—or was it last Thursday?—on the space station, our space program would have gone down the tubes. That simple and that complicated. Because they were going to cut $400 million out—if you cut the $400 million out, you might just as well not have a space program at all, as far as the space station was concerned.

But aren't we saying the same thing here, if you do not provide enough resources to be able to fight in the race—when you talk about the turtle and rabbit or the tortoise and the hare, then we are just not going to be able to finish up on-line. Is that a fair commentary?

Dr. NOTIS. There is a problem in scientific research——

Mr. ROE. Tell me about it.

Dr. NOTIS. And that is you have to spend time in a laboratory doing the research. I think the difficulty that I see here is that the big programs that we need in superconductivity are a follow-up on some of the other programs that we have moved to over the years, and they in turn penalized individual researchers, individual grants because the agencies possibly find it easier to manager larger programs rather than smaller ones. I think that——

Mr. ROE. Would the gentleman yield at that point—I hate to break your train of thought, but it is important to say that is an assumption, the assumption is that because we were going to build a Superconducting, Supercollider, because you are going to build a space station, that we will go on and the whole world falls apart. This is the following point of view, that the assumption that the United States can stay competitive with puny amounts of funding being put into research in the first place is the fundamental error in judgment. When you talk about superconductivity, the Japanese are putting in 18 or 20 percent of the GNP. We cannot even get Congress to stick to—on the issue, let alone putting up substantial funding. I am coming back and saying that if we look into productivity, then we are looking for new capital formation. We are looking for how we are going to build the housing in this country, how we are going to do mass transit and so forth. We got to create the new wealth to be able to do that in the first place. And the way we are going to create the new wealth in science, space and technology in the innovations we are talking about. There we have to make the investment up front in the research. Is that a reasonable point to make?

Dr. NOTIS. Absolutely.

Mr. ROE. That is where we are coming from.

Dr. NOTIS. It is the total budget that we have put to R&D, or the lack of it, that is really a problem. What I was trying to say was that there are many areas where interdisciplinary research is the way to go and a way to tie into industry because you have already set up a mechanism by which you can do the technological transfer. But, at the same time, we need a portion of our scientists who are going to do research in quiet, in peace, in solitude, to think over the long haul. And if we just move money out of that area into the big visible projects, in the end we are going to stab ourselves right in the back. So it is the total amout of funding that is really the problem. We operate at a difficulty again, because the Japanese by and large do not have a large defense-oriented budget; we do. I am not saying that we should not have it, but that is one of the facts of life that we live with.

Mr. RITTER. I think you are making a number of points. And one of which, on the science side of things, is the United States has still won more Nobel Prizes than any other country. I think maybe not on a per capita basis, but we just have loads of Nobel Prizes. Our problem is not that we have not won Nobel Prizes or we have not done the science, but our problem is commercializing scientific advances. And this area of superconductivity is public example number 1. We are going to be on an equal plane in this field of high-temperature superconductivity. We have done it on the science side, from our great universities and our national laboratories and our industrial resource facilities. But will we have the perseverance over time, the "Team America" approach to commercialize this stuff at the spirit of which we are competitive with the Japanese? That is where I think we have every sign that we are going about this the way we have always done it, and they are going about it the way the have always done it; and they have caught up with us after 20 years. And they—we are starting more or less at the same plane. This is what really concerns me. I will say this, I do not think—you mentioned competition for funds, the science community—the science and technology community, the engineering community are simply not competitive with the housing community, with the homeless community, with the social welfare community, with the defense community, with a whole—with the business community that has got particular interests in mind. The community of scientific and technical professions is virtually unheard until after. When the program is there, then they come to compete——

Mr. ROE. Would the gentleman yield.

Mr. RITTER. I yield.

Mr. ROE. If you can indulge me a minute, I know Dr. Rhyne would know this, we mentioned this earlier in another meeting this morning. In the budget make-up which is a complicated mess to begin with, as far as the federal Government is concerned, is a function called "Budget Function 250." Under Budget Function 250, falls all of the space program, all of the National Science Foundation, what else is in there? Housing——

Mr. RITTER. Energy.

Mr. ROE. Energy and research and so forth. So as we extend our efforts and more opportunities in the science and technology field,

it all has to be put through the eye of the needle, so to speak. The more that we grow in that particular thing, reduces the funding in that area. Because it is a simple bookkeeping—not simple, it is a very complicated bookkeeping approach and so forth. And we say—how can I put this, if the people will not provide the resources, they will provide the resources in that function, Budget Function 250. If you ever tried, Dr. Notis, and forgive me today, to get the big university academia together—middle university and small university and to agree on one point, I find that it is extremely difficult to do. Believe me, I do not say that unkindly. They just do not talk to each other. The idea of getting in it—"My God, we cannot get involved, we cannot do lobbying, we cannot do something like that." Those people never get themselves involved. There are times that we got them involved, but it took a year and a half to do it to form this Function 250 budget coalition. And academia set aside for once its intramural sports, and so did industry—we explained to them, unless you get into this thing, and you make an impression upon the members of the different districts throughout this country, we are not going to be able to break through here and get those resources allocated to this Budget Function 250 no matter what we do.

I have to tell you something, they really went to work. And they did a super job, and they—in Budget Function 250, I think we won on our side about a billion and a half, almost 60 percent of the total allocation that was available for so-called new starts this year. Because we got together and did something about it. One thing I think, if you will forgive me on this, I think one thing that the universities have to do and business has to do is they've got to help to start to force the—instead of fighting amongst themselves who is going to whack up the small research grant or the big project and so forth, they got to get together and say how do we put it together to get this done. They got to use their political muscle now. I mean that is the name of the game in this country. That is what we are faced with. And I think it is there to be done.

Dr. NOTIS. Two comments I might make. First of all, I think some of the state programs that have already been established have been successful in getting smaller universities, and larger universities to get together, such as the Ben Franklin Program that we have here, and also to make more ties with industry—to make the technology transfer much easier. So, I think that has been a great benefit that we have had the last 4 or 5 years now in terms of new kinds of things coming into the system. The other thing I might suggest is we have been talking mostly about government funding—maybe because my colleague here is from DARPA, but——

Mr. ROE. She is looking for funding too.

Dr. NOTIS. I think that maybe we should try to put the arm on industry itself. Industry in the United States has not been forthcoming with dollars for new research for the last 20 years now. I think that maybe some self-reliance on industry, maybe some buyback programs by which industry could get benefit for dollars that they put into research from the government in focused areas of research, might be a way for industry to make a full commitment in

a large way. So I think there are new kinds of approaches that we can take, but I think that we've got to do it quickly.

Mr. ROE. You make a very good point. For us on the Science, Space, and Technology Committee or any other Committee, Public Works or whatever, to move in that direction we have to by law and by constitutional structure, by congressional structure we have to work with the Ways and Means Committee. And then it gets back to the—and then it gets back to the tax issue. In other words, there would have been room in that tax bill to start to formulate methodologies to achieve what you are talking about, OK. The change of doing that is like rattling bones in a cage at the moment.

However, when we—there are two questions I would like to ask you—when we run into our public works program, which is truly the infrastructure of the nation, mundane bridges, water supply, blah, blah, blah, blah, and so forth and so on. That truly is the definite formation as to where this country goes, because without that we cannot move at all, universities whether or notwithstanding. One comes back and says, we have matching programs there and reviews that same methodology in the Superfund bill, for example.

Now, two questions—one, would that be a reason or is that considered to be gratuitous—is that a reasonable approach to take? Suppose, for example, Congress was to come down and say we ought to be doing a lot more on science, space and technology as it relates to superconductivity. We consider that a priority issue, and there is not enough resources. We want a special resource made available. Private industry wants to participate. Do it on a 50/50 basis. We will allocate so much to do that. That is one point.

The second point we were talking about is the idea that when we get into what you call "big science" issues such as the debate and the competition taking place on the Superconducting Supercollider. In other words, what state was going to get the grand prize, so to speak? What about the idea of putting language in the authorization bill that would require the agency to regionalize its procurement, so it would not be a question of a particular "big science" project going to Illinois or to Texas or to California or New Jersey or Pennsylvania, like putting all the eggs in one basket, would we be coming back and saying that they would have to look at a national policy and select regions of the country where part of the production would be done in different regions of the country, if you are hearing me. In others words, when we had the 39 States that competed for the Superconductor Supercollider and that was whittled down to the seven now that are in—the last seven to decide, the question was asked, did a lot of congressional support evaporate? The answer is, "yes it did." Then the question is, "when you get down to the one state, will all the congressional support evaporate and only one state?" The answer is, "no, that will not happen, we hope." That is our plan anyway. What about those two elements?

Dr. NOTIS. OK, first of all I think your first point relates to SEMATECH—I see SEMATECH as the first example——

Mr. RITTER. Would you explain, maybe some do not know?

Dr. NOTIS. SEMATECH for those who do not know, is a fairly large program to try to put the United States ahead in the advanced

automation high-speed electronic race, to the tune of $250 million.

Mr. ROE. $250 million, right.

Dr. NOTIS. It is a matching kind of thing. I think that we are going to have to spend a wait-and-see period that we have to find out whether that kind of program works. The problem is, can we afford the wait-and-see——

Mr. ROE. But you also have industrial, private industrial money going into that.

Dr. NOTIS. Right. That is what I am saying. It is matching between industry and government in order to come up with the money. The problem is: do we have the time to play a wait-and-see game to see if SEMATECH works before we try and do it on something? I do not think so. The other thing is in terms of the regionalization. I do not think that any—there is any one group, or any few groups in the United States that have all the good ideas locked in. I think that to a certain extent, regionalization is a good idea. That means that you can have a lot less political infighting, maybe. And hopefully, people will get to work faster. I think it is the same problem with nuclear waste disposal. Everybody wants it in somebody else's state. The thing that concerns me about the Supercollider is as you say, it is "big science" versus "small science."

Mr. ROE. I do not say that. You said that.

Dr. NOTIS. Well, I misunderstood you, then.

Mr. ROE. I do not consider it to be—but other people say that.

Dr. NOTIS. Well, if you have a total amount of funds that is adequate for everybody, then it is not "big science" versus "small science." When push comes to shove and there are only limited dollars around, it is going to be the case between "big science" and "small science."

Mr. ROE. If the gentleman would yield. How would you have voted as a Member of Congress on Thursday when we were fighting a multi-billion issue and the whole Congress concentrated on a point of view of an amendment that was ordered but came back and said the following—remember, every Member of the House is up for election this year—and then we came back and said that we would take $430 or $450 million roughly out of the space station program and they will reassign that. Now, wherever we reassign those funds—reassign it for more housing, what we need in the country, or do we reassign it for housing for the elderly?

In addition, we would provide some of the funding for the homeless that are sleeping on grates, and after we battle the serious matter on that thing of the—what was important in America, the last person, the last member from Massachusetts spoke. He talked about the little 3-year old girl, who is out there with her leg swollen and could not—and this is the United States—and raised such a challenge that the tears would run down your cheek, because it was not the issue of the 3-year old involved, it was a political issue as to whether or not that $450 million—people would go home in this election and say to the citizen, look what we have done for the homeless and whatever, not saying that you destroyed the space program in this country and the economic generators and dynamics of the country. That is what we have to deal with as far as Members of Congress.

I got to tell you something, when that vote was taken we beat that type of situation by 100 votes which was—the coalitions were extraordinary that time, because people thought beyond the 2-year issue. When we come back and we say that the things that we should be doing or can be doing—another point we know in our space program, we cannot operate the space program in this country on $11 billion a year. We cannot do that, and conversely to what they said on the floor, the space program in the country has been reduced by 40 to 50 percent in the last 10 years.

Now we come back with now what can we do to provide new resources if we ever work that out? That gets to the point that you were talking about SEMATECH. I talk now about the CDSF Program which is a space shop. The private industry came and they are going to do—put up a research lab up, they are going to put up all the money—provided, however, provided the U.S. Government puts up—what was it, $750 million?—over a period of 4 years—even if they put it in escrow, in that case, they would be—it could be used as collateral security for them to float their particular financial instrument, and then they would have the money to go with in private, if you are hearing. We came back and said, "Well, should we now be thinking in this country about private enterprise participating more?" Where we would talking about some function of that nature? We would be talking about: "should we be selling space bonds where the funds would be used specifically for our space program?" The average American citizen could participate as they did with savings bonds. Should we be looking for other financial methodologies and other ways to raise funding for our science, space, and technology programs, other than direct appropriations coming each year? There is nothing that comes down the horizon that we can see now that is going to change or further exacerbate this whole budget issue. So that when you are competing and looking into the future of this country, on new jobs, new opportunity in science, space, and technology, we have got to fight the emotional point of view—and legitimately so—of housing, people sleeping on grates, catastrophic illness and all the other things that go with it. We have got to get more votes to be able to get people to agree that science, space and technology is really the future of the country. I did not want to make such a long speech, but nevertheless it was necessary to give you the point of view.

Mr. RITTER. We are going to have to move on.

Mr. ROE. That is what happens when you come to Pennsylvania, you get in such interesting discussions, you want to stay—they are telling me we do not have too much time. That is OK.

Dr. NOTIS. If you put me in a position of saying, do I want scientific research, while I am taking the food out of some child's mouth, then my answer is going to be, no. I want to keep the food in the child's mouth.

Mr. ROE. That is my point.

Dr. NOTIS. On the other hand, I think we live in a time where we have got to sit back and take a look at all of—I ask a bigger question that, and we all have vested interests when we always want to keep those vested interests. So the point is: do I want to take food out of the child's mouth and/or do I want to take a space station that is going to operate or not? I mean I think we got to ask both

ends of the spectrum kind of question. I do not think that we live in the best of all possible worlds. You asked for an answer on the Supercollider—if asked the kind of vote that you asked, I probably would have voted for the Supercollider. In an abstract situation, I probably would have come up with the same kind of arguments that would come up against the supercollider. So that there is no clear cut yea or nay. That depends on the situation that you have to vote on at the given time. I do not think it is a clear-cut issue.

Mr. RITTER. Could I interject one point here? You mention that the conflict between some of this longer-range investment in the science and technology base of America's future, but first is taking food out of a child's mouth. But first of all, we are spending the vast, vast proportion of the Federal budget not on science and technology, but you know two-thirds of the Federal budget is non-defense expenditure, two-thirds out of that trillion dollars, or 70 percent. And what I would say is that if we are looking at the food to feed our people with, if we are looking for medical care, if we are looking for housing, we darn well better create the kind of wealth that allows us to make these investments. And there is this idea of seed corn. You cannot eat the seed corn and still have a crop off into the future. So, somewhere at some point, some resources have to get planted into the ground so that the future crop is available.

Mr. ROE. Wonder, we agree. One more point, if you dare answer. I do not think Dr. Rhyne can, but you may be able to. Not that she is incapable. I do not know that she would want to. We are concerned about the type of political debate that is going on in the nation. And I am not speaking from a partisan point of view—Mr. Bush running for the Presidency, Mr. Dukakis running for President. And we find it difficult to see where they start to stand on science, space, technology and education. What does the university community feel about that? How do we start—how does the university community and academic community try to get that point across to the candidates? Is anything being done? I am just curious.

Dr. NOTIS. Well, first of all again to get back to the larger picture, it should not matter what Bush or Dukakis' point of view of that policy should be. It should be something to my thinking that both parties should have agreed on or else the system should have established a policy in the area. Because there are certain things that transcend party, political kinds of interest. I think that certainly university is concerned, as Roger started out when he talked, about concern over the question of since the university has put into being new programs to turn out people capable of dealing with our high technology world, and some concern about whether or not industry is really prepared to take these people yet. I think that the system is not well worked out, it is not well-greased in order to do that. But just some comparisons, the Japanese are putting out as many, if not more engineers each and every year than we are. The total number of science papers that are put out each and every year are now almost up to what the United States is publishing, and, unless we keep on building an educational system, again it is one more aspect of the race that Don is talking about.

Dr. RHYNE. I would like to make just one quick—some comment to that. The Federation of Materials Societies in fact is putting together some, I think, data and information for both political cam-

paigns to address some of these long-term technology-type issues, and I think they will be forthcoming in the next couple of weeks.

I also would like to as sort of a last remark to remind you that in the particular area of superconductors, I think small businesses need to be kept in mind because although in the low-temperature superconductors or conventional materials, many large companies were involved, the actual production of these materials has come almost entirely from small companies. Now we have a lot of new start-ups and other small companies, and it seems to us, at least to me, that it is the small companies that at least initially take the brunt of the very high-risk possibilities in starting up the new markets which then can allow the larger companies later to actually jump to make a——

Mr. RITTER. That is why the DARPA program, Kay, is so important and so effective and has to continue. Because it just went right out to all these start-ups, the American Superconductor and these wild and woolly people. They got investment capital and got together and you got a company going—this is our ace in the hole.

Dr. RHYNE. That is right. I would also like to—also like to add that, as one venture capitalist told me, that the problem with dealing with government is that you cannot afford it in your start-up company. There are in fact some problems and contracting and so forth and the long lead time before you actually get money in your hand, and we already have problems that are arising from that. These are all issues I think that actually could be and should be addressed by the government. We need to find better ways to get these things done quicker and more expediently.

Mr. ROE. OK. Excellent, very good job. We appreciate you being with us.

Our next panel is panel number 3 which is the panel on photonics. Dr. Melvyn Dixon, department head of the lightwave data links, AT&T Bell Labs, and then Dr. Lawrence Goldberg, Director of the Quantum Electronics, Waves and Beams Program of the National Science Foundation, Washington, DC.

So, I think what we will do is to take Dr. Dixon—how about you going first, Dr. Dixon? We have your statement, but I think that you might want to preclude any reading.

STATEMENT OF DR. MELVYN DIXON, DEPARTMENT HEAD, LIGHTWAVE DATA LINKS, AT&T BELL LABORATORIES

Dr. DIXON. OK. Good afternoon. I would like to thank the Committee for its privilege of giving testimony on an exciting subject area like photonics. My testimony will be in five parts. I will give a brief overview. I'll try to describe benefits that I think photonics has improved and AT&T is working with, and specifically what they are doing in the Lehigh Valley at the Solid State Technology Center, and in the area of competitive position in the world and in the United States and a brief overview of AT&T's position of the role of the federal government.

Photonics is a "killer technology." In less than 10 years the marriage of semiconductor lasers, glass fibers and ultra-sensitive photodectors has completely revolutionized the long distance networks of the world's telecommunications companies.

The United States has been completely rewired with glass fibers. At this very moment, the Atlantic is being spanned with its first lightwave submarine cable system. The Pacific, Caribbean and Mediterranean will be fibered within the next 2 years.

This photonics technology has surpassed both copper coaxial cable and microwave radio systems in terms of information, carrying cross-section times transmission distance by almost an order of magnitude—achieving the astronomical value of 1 10-bit km of a second or 5 million voice-channel miles—with the capability of a further thousand-fold increase still possible.

In addition, photonics is poised to rapidly penetrate and enhance the capabilities of the Si-based computer industry and the military marketplace. The latter developments in the military field will be in the area of avionics and naval control and communication systems, and in both ground and air-borne guided missile systems. AT&T, and specifically the Solid State Technology Center [SSTC], currently being completed here in the Lehigh Valley, will continue to be a photonics leader as the continuing revolution shifts from the transmission arena to that of computing and switching.

And, briefly, the benefits. Benefits have already rapidly accrued, and will continue to accrue in three major areas.

First, to the consumer. The use of photonics in the transmission network has led to a significantly enhanced quality of service, due to the digital nature of laser transmission and the insulating property of glass fibers which make it immune to electrical interference,

Second, an expanded network which has resulted in a more cost-effective communication system.

And finally, enormously higher bandwidth, which offers great opportunities to the consumer in terms of enhanced services, as fiber finally penetrates to the individual homes.

The second benefit is to the computer industry. There has been an inexorable rise in data transmission needs of the computer industry, and it is currently being enhanced by photonic interconnections using LEDs and fiber cable. The benefits arising from the developments are: (a) removal of cable congestion between large mainframe computers and their peripherals; (b) improved data rates and hence reduced costs; (c) improved noise immunity and security of the systems; (d) an emergence of standards for interconnectivity of fiber local area networks, or "LANs," which will allow increased data access and management within factories and office buildings, with attendant productivity increases; and (e) in the not too distant future, intra-computer connections at gigabit per second rates will facilitate parallel processing in the supercomputer industry, with the potential for enormously enhanced "number-crunching" power for computers of the type used by NASA, and Los Alamos[5] and the National Weather Service.

And finally, to the federal government. Benefits from the federal come from the major commitment being made to photonics by the military establishment, which will produce systems and subsystems which are light weight, but with low radar cross-section capability,

[5] Los Alamos National Laboratory.

are hard to tap, capable of producing enhanced flight control, management and display in advanced tactical aircraft and submarines, and able to give long distance control for fiber guided missiles.

Briefly, I would like to discuss the work that is performed by AT&T, and that which will take place at the SSTC. AT&T presently has a broad-based photonics effort in our R&D manufacture, systems integration, installation, operations systems and support.

This capability covers all areas of photonics technology including materials, fiber, device and subsystems R&D which are conducted at Murray Hill, Holmdel, Crawford Hill, and Whippany, NJ, and at Allentown and Reading, PA. Switching systems in photonic field are conducted at Indian Hill, IL. Fiber manufacture is in Atlanta, GA; system manufacture at Merrimack Valley, MA, and device and component manufacturing in Reading, PA.

The SSTC is a further commitment by AT&T to remain at the leading edge of this technology. It is a $100 million investment by AT&T in the future solid state technology development which will encompass materials, processes, devices and subsystem R&D for photonics. The building specifically has been designed state-of-the-art for very low vibration to facilitate microscopic photo devices. It has excellent environmental controls with no expense spared for effluent treatment, safety in gas handling with modern alarm systems, separate elevators for chemical and equipment handling and delivery; clean rooms with ultimate class 100 capability; special services for pure water and gases; and very, very importantly, a topic which you have discussed at great length this morning, proximity to the Reading manufacturing location to facilitate the smooth technology transfer from research and development to manufacturing; and finally, access to the excellent infrastructure of the Lehigh Valley.

Mr. RITTER. You did not mention the great beauty of the architecture and the environment, the work environment for these creative people. Go ahead.

Dr. DIXON. Thank you.

Mr. ROE. I noticed you did list more institutions and establishments in New Jersey than you have in Pennsylvania.

Dr. DIXON. Technology at the SSTC has some central thrusts to the R&D programs, and they will be in four major areas.

There will be further development of the optical components and subsystems which will continue to enhance the existing telephone transmission network of the United States. This will involve development of multi-gigabit optical lasers, LEDs, and photodetection devices. In addition, development of schemes, such as coherent detection to give high density multiplexing of optical channels to fully utilize the enormous fiber bandwidth of over 100 terahertz.

There will be the development of optical analogues of electronic components, for example, optical amplifiers and isolators to eliminate electronic regeneration and optical logic gates which will lead to all optical switching and computing network.

And the work that the SSTC does will be underpinned by the research and development of basic materials and processes in III–V compounds, notably InP and InGaAsP, using the most advanced material growth techniques such as molecular beam, vapor phase and chemical beam epitaxies. These will be used to achieve the

unique device structures, such a quantum well and distributed feedback, which are needed for the ultra high-speed and high optical spectral purity devices needed for this technology.

There will be the integrated photonic device developments (optoelectronic integrated circuits) which will be developed to combine lasers, amplifiers, photodectors and InP based transistors on a single substrate, achieving integration in an analogous manner to silicon integrated circuits.

But prior to that full integration of photonic devices, over the next decade we envision a hybrid integration phase—again similar to that which was developed in the evolution of silicon integrated circuits—in which InP devices will be integrated on silicon substrates to achieve advanced manufacturing technology which will reduce costs and bring those services to make "fiber to the home" cost effective.

In terms of competitive position, AT&T is "the best in the world, including Japan," in the photonics field. Our biased view is that we stand alone in the United States in integrated effort in this technology. It really is "AT&T versus Japan, Inc.," with the battle field mainly the United States marketplace.

There are a few large European corporations, Siemens in Germany, British Telecom and STL in Great Britain, and Thompson CSF and Alcatel in France, plus Northern Telecom in Canada, that are vying for a place in this technology.

There is excellent work taking place in other United States corporations, notably: Corning, specifically in the area of fiber; GTE and Rockwell Collins on photonic devices and systems; and many good but small component manufacturers, who have extremely fierce Japanese competition.

In summary, on the competitive arena, this is an industry that has been targeted by the Japanese Government and electronics industry, which requires high R&D investment, has enormous cost pressures and very short concept to manufacturing cycles of typically 2 to 3 years.

Finally, the role of the federal government. Photonics is a revolutionary technology—with many parallels to the development of the silicon integrated circuit industry. AT&T believes it should evolve to the benefit of the consumer. And this is best achieved in a free market atmosphere.

Specifically, in the telecommunications industry, government should ensure that maximum benefit accrues to the American public. Petty squabbles and the interest of a few individuals or corporation are to be avoided.

We believe Government should actively encourage the use of the most advanced technology, including photonic components and systems, in both industry and federal agencies. It should support mutual free trade with foreign competitors; that it should be very vigilant in ensuring that non-competitive practices—for example, selling below cost to gain market share and eliminate competition—are avoided.

In conclusion, we recommend that the government actively support new technologies such as photonics. However, in a period of fiscal restraint, we feel this is best achieved by government procurement programs which stimulate the development of products

and systems, rather than by direct government subsidy of R&D with no committed final deliverable.

Thank you very much.

[The prepared statement of Dr. Dixon is as follows:]

STATEMENT OF

DR. MELVYN DIXON, DEPARTMENT HEAD

AT&T BELL LABORATORIES

BEFORE THE

SUBCOMMITTEE ON INVESTIGATIONS AND OVERSIGHT

OF THE COMMITTEE OF SCIENCE, SPACE AND TECHNOLOGY

U.S. HOUSE OF REPRESENTATIVES

JUNE 27, 1988

"The Cutting Edge: Science and Technology for America's Future"

- PHOTONICS -

I) OVERVIEW:

Photonics is a "killer technology." In less than ten years the marriage of semiconductor lasers, high purity glass fibers and ultra-sensitive photodetectors has completely revolutionized the long distance networks of the world's telecommunications companies.

The U.S. has been completely rewired with glass fibers. At this very moment, the Atlantic is being spanned with its first lightwave submarine cable system. The Pacific, Caribbean and Mediterranean will be fibered within the next two years.

This photonics technology has surpassed both copper coaxial cable and microwave radio systems, in terms of information

carrying cross-section times transmission distance, by almost an order of magnitude (achieving 10^{12}bit-km/sec or 5×10^{6} voice channel-miles), with the capability of a further thousand fold increase still possible.

In addition, photonics is poised to rapidly penetrate and enhance the capabilities of the Si-based computer industry and military market place. The latter developments will be in the area of avionics and naval control and communication systems, and in both ground and air-borne guided missile systems.

AT&T, and specifically the Solid State Technology Center, (SSTC), currently being completed here in the Lehigh Valley, will continue to be a photonics leader as the continuing revolution shifts from the transmission arena to that of computing and switching.

II) **BENEFITS**:

Benefits have already rapidly accrued, and will continue to accrue, in three major areas.

1) To The Consumer

The use of photonics in the transmission network has led to

a) significantly enhanced service quality due to the digital nature of laser transmission and the insulating property of glass, which make it immune to electrical noise interference.

b) an expanded network which has resulted in a more cost effective system.

c) enormously higher bandwidth, which offers great opportunities to the consumer in terms of enhanced services, as fiber finally penetrates to the individual homes.

2) To The Computer Industry

The inexorable rise in data transmission needs of the computer industry is currently being enhanced by photonic interconnections using LEDS and fiber cable. The benefits arising from these developments are

a) Removal of cable congestion between large mainframe computers and their peripherals.

b) Improved data rates and hence reduced costs.

c) Improved noise immunity and security of the systems.

d) The emergence of standards for interconnectivity of fiber local area networks, LANS, which will allow increased data access and management, within factories and office buildings, with attendant productivity increases.

e) In the not distant future, intra-computer connections at gigabit/sec rates will facilitate parallel processing in the super-computer industry with the potential of enormously enhanced "number-

crunching" power for computers of the type used by NASA, Los Alamos and the National Weather Service.

3. To the Federal Government

The major commitment being made to photonics by the military establishment will produce systems and subsystems which are

a) Light weight, but with low radar X-section capability.
b) Hard to tap.
c) Capable of producing enhanced flight control, management and display in advanced tactical aircraft and submarines.
d) Able to give long distance control of fiber guided missiles.

III) AT&T WORK AND THE SSTC

AT&T presently has a broad based photonics effort in R&D, manufacture, systems integration, installation, and operations systems and support.

This capability covers all areas of photonics technology including materials, fiber, device, subsystems R&D which are conducted at Murray Hill, Holmdel, Crawford Hill, Whippany, N.J. and Allentown and Reading, PA. Switching studies are conducted at Indian Hill in Illinois. Fiber manufacture is in

Atlanta, Georgia; system manufacture at Merrimack Valley, Massachusetts and device and component manufacturing in Reading, PA.

The SSTC is a further commitment by AT&T to remain at the leading edge of the technology. It is a $100 Million investment in future solid state technology development which will encompass materials, processes, devices and subsystem R&D for photonics. The building has been designed

1) for very low vibration to facilitate the microscopic photo devices.
2) with excellent environmental controls with no expense spared for effluent treatment, safety in gas handling with modern alarm systems, separate elevators for chemical and equipment handling and delivery.
3) Clean rooms with ultimate class 10 capability.
4) Special services for pure water and gases.
5) Very importantly, proximity to the Reading manufacturing location to facilitate smooth technology transfer from R&D to manufacturing.
6) Access to the excellent infrastructure of the Lehigh Valley.

Technology at the SSTC

Central thrusts to the R&D programs at the SSTC will be

1) Further rapid development of optical components and subsystems which will continue to enhance the existing transmission network. This will involve development of multi-gigabit optical lasers, LED and photo-detection devices. In addition, development of schemes (such as coherent detection) to give high density multiplexing of optical channels to fully utilize the enormous fiber bandwidth of 10^{14}Hz.

2) The development of optical analogs of electronic components (e.g. optical amplifiers and isolators to eliminate electronic regeneration and optical logic gates which will lead to all optical switching and computing.)

3) This work will be underpinned by the research and development of basic materials and processes in III-V compounds, notably InP and InGaAsP, using advanced material growth technologies such as molecular beam, vapor phase and chemical beam epitaxies. These will be used to achieve the unique device structures, such as quantum well and distributed feedback, which are needed for ultra high speed and high optical spectral purity devices.

4) Integrated photonic devices (opto-electronic integrated circuits) will be developed to combine lasers, amplifiers, photodetectors and InP based

transistors on a single substrate, achieving integration in an analogous manner to silicon integrated circuits.

5) Prior to such full integration of photonic devices, over the next decade we envision a hybrid integration phase (again similar to the evolution of silicon integrated circuits) in which InP devices will be integrated on Si substrates to achieve advanced manufacturing technology which will reduce costs to a level to make "fiber to the home" cost effective.

(IV) COMPETITIVE POSITION

AT&T believes it is "The best in the world, including Japan" in the photonics field. Our biased view is that we stand alone in the U.S. in integrated effort in this technology, It is

AT&T versus "Japan, Inc"

with the battlefield mainly the U.S. marketplace.

A few large European corporations, Siemens in Germany, British Telecom and STL in Great Britain, and Thompson CSF and Alcatel in France, plus Northern Telecom in Canada, are vying for a place in this technology. Also, excellent work is taking place in other U.S. corporations, notably

a) Corning - fibers

b) GTE and Rockwell Collins - photonic devices and

systems

c) and many good, but small component manufacturers, who have fierce Japanese competition.

In summary, this is an industry targeted by the Japanese government and electronics industry which requires high R&D investment, has enormous cost pressures and very short concept to manufacturing cycles of typically 2 to 3 years.

V) ROLE OF THE FEDERAL GOVERNMENT

Photonics is a revolutionary technology (with many parallels to the development of the silicon integrated circuit industry.) AT&T believes it should evolve to the benefit of the consumer. This is best achieved in a free market atmosphere.

Specifically, in the telecommunications industry, government should ensure that maximum benefit accrues to the American public. Petty squabbles, in the self-interest of a few individuals or corporations, are to be avoided.

Government should actively encourage the use of the most advanced technology, including photonic components and systems, in both industry and federal agencies. It should also support mutual free trade with foreign competitors; but should be vigilant in ensuring that non-competitive practices (e.g.

selling below cost to gain market share and eliminate competition) are avoided.

In conclusion, we recommend that the government actively support new technologies such as photonics. However, in a period of fiscal restraint, we feel this is best achieved by government procurement programs which stimulate the development of products and systems, rather than by direct government subsidy of R&D with no committed final deliverable.

BIOGRAPHY

Dr. Melvyn Dixon was born and educated in Leeds, England. He received a Ph.D. in Physics, from the University of Leeds in 1964, for low temperature studies of the Fermi surface of noble metal alloys. From 1964 to 1967 he was a post-doctoral fellow at the University of Pittsburgh where he worked on crystal field and exchange interactions in rare-earth intermetallic compounds.

In 1967, he joined AT&T-Bell Laboratories to work on R&D of magnetic ceramic materials. In 1978 he switched to the field of Photonics and began work on laser transmitter development for the first commercial lightwave systems. He has subsequently supervised an exploratory group working on coherent detection and currently heads a department responsible for development of optical data links for both computer and military applications.

Dr. Dixon has published 20 papers in the fields of low temperature physics, magnetism and photonics and has received 3 patents in these fields.

STATEMENT OF DR. LAWRENCE S. GOLDBERG, DIRECTOR, QUANTUM ELECTRONICS, WAVES AND BEAMS PROGRAM, DIVISION OF ELECTRICAL, COMMUNICATIONS AND SYSTEMS ENGINEERING, NATIONAL SCIENCE FOUNDATION

Dr. GOLDBERG. Good afternoon, Mr. Chairman and Congressman Ritter, and thank you for the opportunity to testify today concerning photonics research at the National Science Foundation.

In the nearly three decades since its development, the laser's use in science and technology has grown enormously, spawning new industries and opportunities for future technology advances. From these origins, photonics, or "lightwave technology," has developed into a field which now covers a broad spectrum of applications—drive areas that are being pursued aggressively worldwide. These include areas such as optical communications, as we have heard, optical signal processing, optical switching and computing to name a few. Optical fiber communication links that now span the country and indeed the ocean—are a familiar first example.

As our societies become increasingly information-oriented, the need for advanced capabilities in sending and manipulating information continues to grow rapidly. Photonics, in which light or photons, rather than electrons, is used to carry and process information, offers enormous potential increase in bandwidth or carrying capacity, in speed, and in totally new functions compared to conventional electronic based systems. The changes will not occur overnight, nor will electronics be even substantially replaced in the near term, the emergence of a hybrid photonics/electronics technology being most likely. However, the implications of this technology for our nation's future economic vitality are clear.

We face a major challenge in photonics from our trading partners in the Far East as well as in Europe. They are committed to success and their investments in research, development and manufacturing—from industry and from Government—are both substantial and long-term. The United States has been a leader in much of this technology, but our leadership position, particularly in the commercial sector, is frankly, in my opinion, slipping away. Witness the ubiquity of Japan's digital compact disc player in the home, with its state-of-the-art laser diode source. In this field as in others, technology innovation, and its concomitant underlying structure of basic research knowledge, will be a crucial ingredient to maintaining a competitive edge.

The National Science Foundation, through its support of fundamental research in science and engineering, has invested considerably of its resources, in past years and currently, in activities that are both related to and potentially useful for photonic systems. The funding support—to individual investigators, groups and centers—is spread through several Directorates, Divisions and Programs at the NSF, and spans research from basic physical concepts, through materials science, component research, device physics, fabrication technology, and systems concepts and integration.

The principal support for photonics research at NSF comes from programs within the Engineering Directorate. Nearly 3 years ago, the Lightwave Technology Program was established, based on recommendations by an NSF workshop held to identify research op-

portunities in the field. The spotlighting of this research area, by focusing within a new program the laser and information systems-related components from other programs, indicated the importance that was placed by the Engineering Directorate in what were to be called "emerging technologies." The current program budget of approximately $3.1 million supports research by individual investigators and groups on such topics as optical waveguiding, high-speed communications, optical computing, switching and logic functions, optical sensing, integrated optoelectronic systems, and semiconductor laser systems technology.

The Quantum Electronics, Waves and Beams Program within the Division of Electrical Communications and Systems Engineering funds approximately $2.2 million, about half of its budget, in photonics-related research. This program, which was a progenitor of the Lightwave Technology Program, supports research on modern optical and laser-related technologies, including new coherent sources and concepts, ultrashort pulse technology, nonlinear and coherent phenomena, and associated laser devices and techniques. The program also supports research on free electron lasers as well as on microwave and millimeter wave technologies, some of which now utilize techniques of optical control and probing.

The Solid State and Microstructures Program, which is also within the Division of Electrical Communications and Systems Engineering, focuses on component research, device physics, fabrication technologies, and integration of electronic components and elements of prospective optoelectronic integrated circuits. This latter goal of a fully integrated optoelectronic circuit on a chip has major future technological implications. The research is primarily oriented toward work on compound semiconductor materials. It includes work on multi-quantum-well photon detectors and laser sources as well as high-speed electronic switching devices. About $2.7 million from this program is spent in support of photonics-related activities.

The advent of the Engineering Research Centers program has provided NSF a new mechanism to focus research funds into technologically important areas. Of the 14 Engineering Research Centers—or ERCs—that are currently funded, three of these are in areas directly or partly supportive of photonics research, namely the Center of Optoelectronic Computing Systems, at the University of Colorado-Boulder and Colorado State University; the Center for Compound Semiconductor Microelectronics at the University of Illinois; and the Center for Telecommunications Research at Columbia University. The current funding level of these three Centers is approximately $6.3 million, approximately $3.6 million of that being in photonics activities. In addition, the Engineering Directorate has a program on Industry/University Cooperative Research Centers aimed at stimulating industrial support of university research, and in a number of these Centers there are research activities relating to photonics.

In the Mathematical and Physical Sciences Directorate, the Division of Materials Research, which supports, incidentally, superconductivity work, also supports fundamental research on materials that are crucial to future advances in future advances and devices and components for photonics technologies. With the Ceramic and

Electronic Materials Program, for example, approximately $1 million is spent in photonics-related areas, approximately 13 percent of that program's budget. Additional supportive materials research efforts are contained in other programs throughout the Division, such as Solid State Physics, Solid State Chemistry, and in Materials Research Laboratories and Materials Research Groups.

Furthermore, the National Science Foundation is currently reviewing a number of proposals for the new Science and Technology Centers Program, and these are—some of these are advanced materials areas which will also have importance to future photonic systems.

As you requested, Mr. Chairman, I have provided a brief overview of NSF's activities in support of photonics research. Through its diversity of support of forefront academic research in science and engineering, and most importantly by its commitment to the training of future generations of researchers, the National Science Foundation continues its essential role in helping to maintain the Nation's technological leadership position.

Now, let me address a few personal comments, Mr. Chairman. The important question then, is this sufficient? In my view, the answer is, that it is not. The National Science Foundation, with its available limited resources, provides only one ingredient to the overall investment picture, although a unique and essential one in its support of the academic infrastructure. Other government agencies, such as the Department of Defense, NASA, Departments of Energy and Commerce, have their own specific mission interests. What then should the role of government be in terms of overall coordination to help provide a balance, a focus and an integrated systems objective? What efforts are we as a nation making to implement our basic research discoveries into manufacturable competitive systems and products? Are activities in the Defense Department's sector reconciled to the prospects of important potential contributions in the civilian sector? In this light, are some of our best high-tech firms, comfortable as they may be in the restricted and familiar world of contract research, are they able and interested to compete in the commercial marketplace? Can our industries regain the necessary long-term perspective to research and investment? And a final thought, have we abrogated technical leadership in an area such as telecommunications by having fragmented a national resource, the AT&T Bell System, which had a capability to provide full integration of the technology?

This concludes my remarks, Mr. Chairman. I would be pleased to answer any questions that you may have at this time.

[The prepared statement of Dr. Goldberg follows:]

TESTIMONY

Dr. Lawrence S. Goldberg, Director
Quantum Electronics, Waves, and Beams Program
Division of Electrical, Communications, and Systems Engineering
National Science Foundation

Committee on Science, Space, and Technology
Subcommittee on Investigations and Oversight
U.S. House of Representatives

Bethlehem, Pennsylvania
Monday, June 27, 1988

"Photonics Research at the National Science Foundation"

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In the nearly three decades since its development, the laser's use in science and technology has grown enormously, spawning new industries and opportunities for future technological advances. From these origins, photonics, or lightwave technology, has developed into a field which now covers a broad spectrum of applications-driven areas that are being pursued aggressively world wide. These include areas such as optical communications, optical signal processing, optical switching and computing, to name a few. Optical-fiber communication links that now span the country are a familiar first example.

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The National Science Foundation, through its support of fundamental research in science and engineering, has invested considerable of its resources, in past years and currently, in

activities that are both related to and potentially useful for photonic systems. The funding support - to individual investigators, groups, and centers - is spread through several Directorates, Divisions, and Programs at NSF, and spans research from basic physical concepts, through materials science, component research, device physics, fabrication technologies, and systems concepts and integration.

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for example, currently funds approximately $1M, about 13% of its budget, in photonics related areas. This research comprises characterization of materials, including optical and electronic properties; processing of thin-film compound semiconductors; bulk crystal growth, including nonlinear optical materials; interfacial phenomena; and superlattice and quantum-well multi-layered structures. Additional supportive materials research efforts are contained in other programs throughout the Division, such as in Solid State Physics and Solid State Chemistry, in Materials Research Laboratories and Materials Research Groups, and in National Facilities such as the University of Wisconsin and Cornell University synchrotron light sources.

Furthermore, NSF is currently reviewing a number of proposals for the new Science and Technology Centers Program that are in advanced materials areas of potential importance to future photonic devices. In the Division of Physics, the Atomic, Molecular, and Plasma Physics Program funds experimental efforts in metrology and spectroscopy of atomic, molecular and plasma systems, where laser methods are used nearly pervasively, at key points or throughout. Investigators supported in such programs, as well as in Chemistry, Biosciences, and other areas at NSF, have also contributed in many cases to important advances in lasers and optical measurement techniques.

As you requested, Mr. Chairman, I have provided a brief overview of NSF's activities in support of photonics research. Through its diversity of support of forefront academic research in science and engineering, and by its commitment to the training of future generations of researchers, the National Science Foundation continues its essential role in helping to maintain the Nation's technological leadership position.

This concludes my prepared remarks, Mr. Chairman. I will be pleased to answer any questions you may have at this time.

Mr. ROE. I see that the details of the hearing stimulated your further review. Let me ask the questions. The last panel that discussed superconductivity, they were discussing some of the problems, but when you look at Dr. Dixon's testimony, I mean, it sounds like from your testimony we are doing really great and everything is going well. So do we really have the same kind of problems in the photonics area that we have in superconductivity? And why would you think that the United States firms have been really pushing—they seem to be pushing this foreign industry, because of it being commercially viable?

Dr. DIXON. It is undoubtedly extremely commercially viable now. But I think that the level of effort is probably in the electronics industry greater in Japan, a totally integrated effort and power. So, I think that there are some dangers one could see on the horizon in photonics.

Mr. ROE. Well, we seem to be doing better. We seem to be more dynamic and more alive and active in the photonics sector than we are in superconductivity.

Dr. DIXON. Yes, and I think it was—it is a manifestation of the fact that it entered into a key resource within telecommunications.

Mr. RITTER. It has been around longer and there is more going on.

Dr. DIXON. Yes, that is right. I think that the embryonic part of the laser and fiber research was done at the end of the 1950's. Its full commercial implementation came at the end of the 1970's. And now you are seeing the very rapid escalation. But I think there is a message there, that it took close to 20 years of commitment and concentrated effort within a national resource then which is AT&T——

Mr. ROE. Having got to this point where——

Dr. DIXON. And were always times where it was wondered if it would be a viable technology.

Mr. RITTER. Would that have happened in a post-divestiture of AT&T, that long-term commitment, that patient——

Dr. DIXON. I think AT&T has a commitment for continued R&D research which is still there post-divestiture. I think that the commitment to the SSTC is an indication of that. But it is a very expensive business.

Mr. ROE. In your view, how would the average—you mentioned an interesting thing about the average home changing when we get to the point of being able to get to each phone by television—how do you see that? What do you see happening?

Dr. DIXON. If I give you an opinion, it would obviously be speculation and my history is that scientists are never very good at predicting what the——

Mr. ROE. Neither are politicians——

Dr. DIXON. What the consumer would like. But obviously——

Mr. ROE. What are the potentials then?

Dr. DIXON. The potentials are that one could have total management of one's services, banking services brought to your home, shopping, working at home and lots of things which are only driven—only restricted by the costs at the moment. And it will be when those products and services, your CD laser-type prices are available to offer those services into the home. I think post-divesti-

ture, there are some very aggressive firms who are prepared to offer it, the technology if it is at the right price.

Mr. RITTER. Or if the federal government will allow them the opportunity to do that.

Dr. DIXON. Yes, yes.

Mr. RITTER. Could I—Dr. Goldberg, I would like to follow up a little bit on your comments, because they are somewhat at odds with Dr. Dixon's in terms of your view of the total situation. I tend to feel that given the kind of national focus that the Japanese put on photonics, particularly the optical electronic combinations where they—the general consensus is they are beating us hands down in terms of the overall applications of these things, compact discs is one of the examples; but what would you suggest—you asked some questions at the end of your testimony—what would you suggest—if you can go over that and see if you could give us some answers what at least in your own opinion we should be doing in answering those questions.

Dr. GOLDBERG. I asked those questions as perhaps a way of stimulating thought and discussion points, because I think that the United States has enormous capability and it is a question of how we focus that capability and bring in government, industry and the academic community to work towards what are really long-term technological problems.

At the National Science Foundation, we have a focus on the long term, and I think that this is a technology where it is here today, it has emerged—but there is more to come. And we have to be able to respond to those research challenges.

The area of photonics is going to be one of research discoveries which will open new opportunities that we can perceive but not really identify as products. And we have to be at the forefront of that research in order to be able then to carry out the development.

I think the Japanese are clearly ahead in a number of crucial areas. In the laser diodes area, they are clear leaders. The diodes that are part of each compact disc are at the state-of-the-art such that even researchers at universities will buy a compact disc recorder, cannibalize it for the diode, and have it cheaper than they can obtain in the open marketplace.

It is that ability to mass-produce the products at the state-of-the-art where the Japanese clearly, I believe—there should have been some way how, we as government, and industry and academia have to come to deal with that.

Mr. ROE. Let me ask you something if I am not breaking your train of thought. How do you think that the why or how—do you think that the Japanese and the Dutch, I guess, right?, capture or develop the market in that? When we wrote compact discs, we were capable of doing that, or were we?

Dr. GOLDBERG. I think the Japanese—it has been mentioned in the areas of discussion on manufacturing—clearly have the commercial marketplace as the center of their focus; products that can be produced, produced effectively by quality manufacturing and sold to a mass market. And that is the focus that they have in much of their work.

Mr. RITTER. The society focus.

Dr. GOLDBERG. We have a different focus in some of the major research corporations that we have, and that addresses some of the comments I made in my closing remarks is that some of our very best high-tech firms are not in that competitive commercial marketplace. They are used to dealing in the contract research for Defense or through NASA; agencies where you would produce very state-of-the-art capabilities, but in small quantities, for price is not so much the issue. To compete in the commercial marketplace, you have to develop a different philosophy, and it is a difficult world for them to consider entering. And I think that is a resource that we have that is not being used effectively——

Mr. ROE. Coming through my mind there is the whole debate of the emergence of high-resolution television, for example. That is a very interesting debate considering that the technology is there now and we come back to ourselves and we say that—what are the elements that drive the Government's decisionmaking process? Then one has to come back and say, well, we can get into that right away, but we really would have to in effect replace every television set in the country. So I am sure there is a negative drive there. But nevertheless, the quality of the high-resolution television is so far superior, and yet we waiver.

Mr. RITTER. Mr. Chairman, if I may respond on that. The Japanese have worked for 17 years in a coordinated basis, led by in each case a national network, to provide a better television at—of a large distance—not just marginally better but a lot better. And we just did not do that.

Mr. ROE. Yes.

Mr. RITTER. Thornton Bradshaw, who was vice chairman of RCA at the time, it was one of these business forums—I led a panel. He mentioned that we might as well in America forget about manufacturing, because it can be done so much cheaper and better offshore—in the meantime, of course, RCA was manufacturing—was manufacturing defense avionics for the F16. That in a very real sense, your point is well taken. The main thing about AT&T, it has been in this consumer electronics, when you come right down to it, with a telecommunications focus. But we have gotten so far out of consumer electronics, that when it comes to doing the compact disc, we are not even in the game. When it comes to doing a high-definition television, we are not even in the game. I think this transfer from DOD work has got to be a much higher priority, or to somehow use those skills to get in and back into the commercial marketplace. It has got to be a priority.

Mr. ROE. There are two auxiliary points there: one, the battle we had to fight on the Landsat Program in getting resolution on our Landsat 6 and 7, versus the work that was going on in France at the time on the spot for extra imaging; and then, of course, the defense work the Japanese are doing. We had to literally use every bit of the muscle we had in every direction on a bipartisan basis on that particular one. We were almost to say, when we are in tight budget times, we will give that up to the French in the SPOT program and we will give it up to the Japanese. Let me ask you something: one other point, with the advent of the fiber-optic which would, in effect, would literally revolutionize communications,

what in your assessment would become of the satellite communications industry?

Dr. DIXON. I think it is extremely difficult for the satellite communication business to compete, and in terms of quality and service, and because of the enormous band that you got in the optical field, you got significantly wider bandwidth, so you are distributing costs over bandwidth. It now seems to be that the technology of choice is fiber, especially as you enter into the computer industry, where security of information is very important. If you put it on the satellite, it is basically available to anyone.

Mr. ROE. But you would be talking, when you speak about the state-of-the-art, one would be speaking about where you had the distribution system areas and can establish the distribution systems?

Dr. DIXON. Yes. You can in theory make fiber-optic systems very difficult to tap, not the simple point-to-point that we see now; but there is a need for protection of the consumer, especially his personal records within the communications systems, and fiber is good for that.

Dr. GOLDBERG. There is a point I think where satellite communication may have a bearing in the area of direct broadcast.

Mr. ROE. Yes.

Dr. GOLDBERG. And there is an area which the several Japanese companies I am familiar with are targeting as part of their long-term research—the very compact receivers, because they see that as another mass market opportunity.

Mr. ROE. You are talking from satellite to direct broadcasting.

Dr. GOLDBERG. To the home.

Mr. RITTER. The Japanese are creating a new television system in Japan and it will—high-definition television—will be demonstrated this summer in department store windows. And they will do it by direct broadcast satellite, and they—the Japanese population—will see the Seoul Olympics in department store windows on large screen, ultra high-resolution definition television that is akin to a projected 35 mm slide. This is fantastic, and I guess I am really concerned when I see that the VCR and the compact disc and high-definition television, and then I see on the horizon superconductivity just changing the way of the world; and I see photonics essentially having a similar impact. I see AT&T out there, but I am not sure that the scope and the breath of the national interest in photonics and photo-optoelectronics is anywhere near in this country what it is in Japan as a kind of national priority focused for the economy, for the society. And that is where you think some of your questions are pertinent, because we just have been faced with a new model which is a lot more dynamic in terms of getting science into the commercial marketplace. And I am not sure we've learned yet how to respond.

Mr. ROE. Let me be a devil's advocate. I was saying earlier, when we achieved the moon, and after we had achieved that goal, we threw away the Saturn rocket for example, OK. Now we find that we have a catastrophe with the accident that took place with our Space Shuttle, and one of the debates that had arose in Congress a little bit was, well, in view of the budget problems and blah, blah, blah, blah, why don't we work with the Soviets with their MIG

rocket, that is comparable to the Saturn, why don't we work with the Chinese with the Long March rockets? It seems to be the idealization of the satellite launching facility. Why don't we work with the Soviets on the Proton rocket? Why shouldn't there be an international relationship? If it had not been for the Ariane missile—or the Ariane launching facilities—we would not have been able to do what we had done and kept ourselves going the last year or two. What do you say about that? We provided for example, in the Superconducting Supercollider, we provided for a minimum—I think it was 25 percent international participation. The ceiling was 33 percent, no more than 33 percent. And we provided in there that no segment or element or part, such as, for example, the magnets, could be produced by any foreign producer of more than 33⅓ percent. In other words, we did not want the Japanese to come in and say, well, we will take over the magnet end of it and we will give you $2 billion, but we will provide the magnets for the program. But the question is that we cannot do that alone, supposedly. We should use foreign participation. How do you see that going? Should we be doing more with the Japanese? Should we be doing more with the Chinese, the Soviets and so forth?

Dr. DIXON. Well, certainly the Japanese, from an AT&T perspective, kept us very honest. And certainly at AT&T, they are our major challengers to make us a cost-competitive organization. They do know how to take things from the R&D lab and bring them to fruition. In a sense restricting them, I think, as I said in my testimony—that maybe limiting their access to our marketplace is perhaps not the best thing to do. It makes U.S. corporations competitive, they need to be competitive, they need to develop those skills. What we do need to enjoy is that as a nation, they do not do uncompetitive things by our standards—that they do not bring products so far below the cost of producing them that they do take within our institutions the drive to make money. So I am not sure at which moment our conception in the photonics industry is that we should marshal them to stop imports in Japanese goods.

I think when I alluded to dangers, I think there is Bruce Dunnell, as you know, in the audience who is the AT&T representative on SEMATECH. There is the danger that the enabling technologies in lightwave, in photonics could end up being in Japan. There is the danger, although I would agree that areas like the compact discs are areas where the Japanese have a commercial advantage. There is a danger down the line that there could be an erosion of any parity or leadership in the photonics field if the enabling technologies, the sorts of the thing that SEMATECH has been set up to establish, that could occur. There is a danger, because of the lack of broad-based integrated effort in photonics in this country.

Mr. ROE. And one of the arguments spit up by the scientific community and academia, or scientific community more frequently, and it had to do with the inertia, so to speak, or our space program even before the *Challenger* accident. They said, here we have young scientists, middle-aged scientists, older scientists working for years, a whole lifetime—I am thinking particularly on the Mars Observer, and then because of policies of government, was not really acting alone, but the priorities changed and the launching of this particular satellite which would have enhanced our scientific

knowledge was put on the back burner, so to speak, and it is years behind launching, 10, 12 years at least. Therefore, the attitude of young people getting involved in the scientific field, or the satellite aspect of it in some of the new exotic approaches to, you know, Galileo, and, in general, the other things is, "why bother?" So therefore part of academia comes back somewhat distressed and concerned because it takes so long. People do not want to spend their whole lifetime doing something, and then never see it come to fruition. It is reasonable to assume that when we get to a point where, say, like in Japan and so forth, where they are so far ahead and so forth and it is not just necessarily the impact upon a manufacturing company in the United States or manufacturing companies in the United States on a particular object, but it would seem to me they could also affect our research base in the first place. Why bother to get into this kind of thing if the Japanese are going to be able to do it at this particular moment? What are we wasting our time for? And if we could build it, we cannot build it competitively. Do you understand what I am trying to say? So I am wondering—when we start talking about cutting back our resources, our country's resources in advanced research and so forth, will it not only affect the industry per se but also affect, I would think affect our academic research base.

Dr. DIXON. Yes. I totally agree that it requires, I think, as we demonstrated in the photonics field and by the Japanese themselves, that it is a decision about what you are going to do and a commitment to those priorities to follow them through at all levels for R&D, for the development of the tools to get the products out.

Mr. ROE. Let me ask Dr. Goldberg, it seems to me that we had the leg up on photonics. It was not something that just came out of the blue. Why do you think that we—is it because of a lack of Federal resources to universities—what deterred us from really getting into it, in your observation?

Dr. GOLDBERG. Well, I think we are in it.

Mr. ROE. No, no, no. We are in it now because the Japanese——

Dr. GOLDBERG. We have been——

Mr. ROE. We have sluffed off of it, now we are back into it all total. In other words, why didn't we take an interest in the consumer end of it? Any particular reason? I am just wondering.

Dr. GOLDBERG. Well, I think that is a question that has been grappled with by other panelists in manufacturing, and I have tried to allude to my own thoughts on it the earlier comments. I think we have to become—our industry has to look more toward the commercial marketplace in competing. In these new technologies, we are going to need the people, the young researchers, engineers who are going to be trained in these technologies. We have to make sure that we have fellowship programs which—that there are people attracted to these fields. As a comment to you, as NASA——

Mr. ROE. I did not form that question. I remember back in Dumont, PA and going back to the Kefauver hearings and the little television tube. At time they were just coming out and blah, blah, blah—well, we knew—we were the ones who dominated the television industry at that point. You would think—and we knew what they were doing in photonics and so forth. And I think our

industry knew that they were going to have problems with the Japanese. And we did not do anything about it. And the whole television tube industry is out of the nation pretty much as you know.

Dr. GOLDBERG. Yes.

Mr. ROE. Well, why didn't we do something about that? We just let it go. We are doing the same thing with the CD's and everything else. We just let it go. Go ahead.

Mr. RITTER. I think—I have been grappling with this and listening to people like yourselves and other members of Congress. I think it is a philosophy, it is a long range philosophy or a race, or a kind of an Olympic—an economic Olympic race of being No. 1, and it is a daily process that goes along with this philosophy of constantly improving. It goes back to the quality thing; constantly improving your process that you are engaged with on the production line. We are constantly improving the billing technique in the accounting department. We are constantly improving the product engineering or the product design or the product—the creation of new products. There is a consistent desire to change for the better. I am thinking, you know, all of us—we watch the football game on Sundays, this has not occurred to us that there is something far better out there—it was not occurring to our people in industry. I mean we had great stereo. It was not kind—it is a way of life—it is a way of life to work, it is a way of education; and I think what is happening is we are getting back into that. I think we are going to be fierce competitors, but there is a gap in there where I think we were in fact unhappy and kind of forgot about the "cutting edge" and other people took it over.

Mr. ROE. I am not so sure of that.

Mr. RITTER. Look at IBM and——

Mr. ROE. I am thinking about Disney World. Now, here the Disney organization they are starting—many companies are doing it now, their major operation in Tokyo. They have just announced they are going to set up a Disney World in France, I believe, outside of Paris and so forth.

Mr. RITTER. A lot of American companies have done it. 3M is an American company has always been out there, IBM. The people who have been faced consistently with global competition, who always had to be out there on the front lines, and never were able to relax, are out there today and in good shape. But those who kind of had the domestic American market as the steel industry——

Mr. ROE. Well, did American industry just take a bad attitude? Did American industry just come back and say, too bad, that is a piece of junk, you are going to get it whether you like or not. And somebody came forth and put a better product on the market.

Mr. RITTER. That is exactly right.

Mr. ROE. Sure. Well, it certainly has been provocative, but—and we appreciate your testifying. I do not have any more questions. Do you?

Mr. RITTER. Not at all. And I want to thank you.

Mr. ROE. Well, thank you very much for being with us, and a lot of good ideas emerged today.

Dr. DIXON. Thank you, I appreciate it.

Mr. ROE. All right.

Mr. RITTER. Thank you, Mr. Chairman.

Mr. ROE. Well, I guess there is nothing else, and therefore the hearing stands adjourned. Thank you all very much.

[Whereupon, at 3:15 p.m., the subcommittee adjourned, subject to the call of the Chair.]

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